Chapter 6
Industry, Technology, and the Global Marketplace

Highlights

U.S. Technology in the Marketplace

- **The United States continues to be the leading producer of high-technology products, responsible for about one-third of the world's production.** Although the margin of U.S. leadership narrowed during the 1980s when Japan rapidly enhanced its stature in high-technology fields, by 1998 U.S. high-technology industries had regained some of the world market share lost during the previous decade.
- **The market competitiveness of individual U.S. high-technology industries varies, although each maintained strong, market positions over the 19-year period examined.** Three of the four science-based industries that form the high-technology group (computers and office machinery, pharmaceuticals, and communications equipment) gained world market share in the 1990s. The aerospace industry was the only U.S. high-technology industry to lose market share from 1990 to 1998.
- **Technology products account for a larger share of U.S. exports than imports, thereby making a positive contribution to the U.S. overall balance of trade.** A trend of declining trade surpluses in technology products reversed after several years during the mid-1990s. Between 1990 and 1995, trade in aerospace technologies consistently produced large—albeit declining—trade surpluses for the United States. Since then, U.S. exports of aerospace technologies, electronics, biotechnologies, and software have outpaced imports, leading to increasing trade surpluses in 1996 and 1997 before narrowing slightly in 1998 and 1999.
- **The United States is also a net exporter of technological know-how sold as intellectual property.** Royalties and fees received from foreign firms have been, on average, three times greater than those paid out to foreigners by U.S. firms for access to their technology. U.S. receipts from licensing of technological know-how to foreigners plateaued at about $3.5 billion between 1996 and 1998. Japan is the largest consumer of U.S. technology sold as intellectual property; South Korea is a distant second. Together, Japan and South Korea accounted for more than 44 percent of total receipts in 1999.

New High-Technology Exporters

- **When a model of leading indicators is applied, Ireland and Israel appear to be headed toward prominence as technology developers and exporters to global markets.** Ireland led the group of 15 small or less-advanced countries examined in three of four leading indicators and received the second highest score in the fourth, technological infrastructure. On that indicator, Israel ranked first because of its large number of trained scientists and engineers, highly regarded research enterprise, and contribution to scientific knowledge. Hungary and India also posted strong scores on at least three of the four indicators.

International Trends in Industrial Research and Development

- **Internationally comparable data show the importance of service-sector research and development (R&D) in several industrialized countries.** In 1997, service-sector industries, such as those involved in communications or computer software development, accounted for 20 percent of all R&D performed by industry in the United States and in the United Kingdom, 15 percent in Italy, and 10 percent in France. Although it has increased in recent years, service-sector R&D still accounted for only about 5 percent of all R&D performed by industry in Germany and in Japan.
- **In most industrialized countries, the aerospace, motor vehicle, electronic equipment, and pharmaceutical industries conduct the largest amounts of R&D.** In the United States, industries making computer hardware, electronics, and motor vehicles led the nation in R&D. Japan's electronic equipment industry was the leading performer of R&D throughout the period reviewed, followed by its motor vehicle industry. Manufacturers of electronics equipment, motor vehicles, and industrial chemicals have consistently been among the top five performers of R&D in the European Union.

Patented Inventions

- **In 1999, more than 153,000 patents were issued in the United States, 4 percent more than were granted a year earlier.** This record number of new inventions, resulting in new patents, caps off nearly a decade of year-to-year growth during the 1990s. The proportion of all new patents granted to U.S. inventors has generally risen since the late 1980s, reaching 55 percent in 1999.
- **Foreign patenting in the United States continues to be highly concentrated by country of origin.** In 1999, Japan and Germany accounted for slightly more than 58 percent of foreign-origin U.S. patents, and the top four countries, Japan, Germany, France, and the United Kingdom, accounted for 70 percent. Both South Korea and Taiwan dramatically increased their U.S. patent activity in the late 1980s, and in 1999, each was awarded more U.S. patents than Canada, historically one of the top five nations patenting in the United States.
- **Recent U.S. patents by foreign inventors emphasize several commercially important technologies.** Japanese patents focus on consumer electronics, photography, photocopying, and, more recently, computer technology. German inventors are developing new products and processes associated with heavy industry, such as motor vehicles, printing, advanced materials, and manufacturing technologies. Inventors from Taiwan and South Korea are earning an increasing number of U.S. patents in communications and computer technology.

Venture Capital and High-Technology Enterprise

- **The amount of money managed by venture capital firms grew dramatically during the 1980s as venture capital emerged as an important source of financing for small, innovative firms.** In the early 1990s, the venture capital industry slowed as investor interest waned and the amount of venture capital disbursed declined. But this slowdown was short lived: investor interest picked up in 1992, and disbursements began to rise again in 1993. Both investor interest and venture capital disbursements continued to grow through 2000.

- **Internet companies attracted more venture capital than any other technology area.** In 2000, venture capital firms disbursed nearly $90.6 billion, of which more than 45 percent went to Internet firms. Telecommunications companies were second with nearly 17 percent, and companies developing computer software or delivering software services were third with just more than 14 percent.

- **Little venture capital is used as seed money.** During the past 10 years, money given to entrepreneurs to prove a concept or to support early product development never accounted for more than 6 percent of total venture capital disbursements and most often represented only 2 to 4 percent of the annual totals. In 2000, seed money accounted for just 1.4 percent of all venture capital disbursements, whereas money for company expansion was about 61 percent.

Introduction

Chapter Background

Science & Engineering Indicators 2000 showed that advances in information technology (IT) (i.e., computers and communications products and services) drove an increase in technology development and allowed the United States to increase technical exchanges with its trading partners.[1] This edition of *Science and Engineering Indicators* examines many of the same indicators, with additional perspectives provided by international data on service industries and on patenting activity in two new areas, human DNA sequencing and Internet business methods. New data on applications for U.S. patents by residence of inventor have also been added.[2]

Chapter Organization

This chapter begins with a review of industries that rely heavily on research and development (R&D), referred to here as "high-technology industries."[3] High-technology industries are noted for their high R&D spending and performance, which produce innovations that can be applied to other economic sectors. These industries also help train new scientists, engineers, and other technical personnel (see Nadiri 1993; Tyson 1992). Thus, the market competitiveness of a nation's technological advances, as embodied in new products and processes associated with high-technology industries, can serve as an indicator of the economic and technical effectiveness of that country's science and technology (S&T) enterprise.

The global competitiveness of the U.S. high-technology industry is assessed through an examination of domestic and worldwide market share trends. Data on royalties and fees generated from U.S. imports and exports of technological know-how are used to gauge U.S. competitiveness when technological know-how is sold or rented as intangible (intellectual) property. Also presented are new leading indicators designed to identify those developing and transitioning countries with the potential to become more important exporters of high-technology products over the next 15 years.

This chapter explores several other leading indicators of technology development by examining changing emphases in industrial R&D among the major industrialized countries and comparing U.S. patenting patterns with those of other nations in two important technology areas, human DNA sequencing and Internet business models.

The chapter also examines venture capital disbursements in the United States by stage of financing and by technology area. Venture capital is used in the formation and expansion of small high-technology companies.

U.S. Technology in the Marketplace

Most countries acknowledge a symbiotic relationship between investment in S&T and success in the marketplace: S&T support competitiveness in international trade, and commercial success in the global marketplace provides the resources needed to support new S&T. Consequently, the nation's economic health is a performance measure for the national investment in R&D and in science and engineering (S&E).

The Organisation for Economic Co-operation and Development (OECD) currently identifies four industries as *high-technology* (science-based industries whose products involve above-average levels of R&D): aerospace, computers and office machinery, communications equipment, and pharmaceuticals.[4]

High-technology industries are important to nations for several reasons:

- High-technology firms innovate, and firms that innovate tend to gain market share, create new product markets, and/or use resources more productively (National Research Council, Hamburg Institute for Economic Research, and Kiel Institute for World Economics 1996; Tassey 1995).
- High-technology firms develop high value-added products and are successful in foreign markets, which results in greater compensation for their employees (Tyson 1992).
- Industrial R&D performed by high-technology industries benefits other commercial sectors by generating new products and processes that increase productivity, expand business, and create high-wage jobs (Nadiri 1993; Tyson 1992; Mansfield 1991).

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[1]This chapter presents data from various public and private sources. Consequently, country coverage will vary by data source. Trend data for the advanced industrialized countries are discussed in all sections of the chapter. When available, more limited data for fast-growing and smaller economies are added to the discussion.

[2]Trends in the number and origin of U.S. patent applications provide a more current, albeit less exact, indication of inventive patterns than that provided by the chapter's examination of U.S. patents granted.

[3]No single preferred methodology exists for identifying high-technology industries, but most calculations rely on a comparison of R&D intensities. R&D intensity, in turn, is typically determined by comparing industry R&D expenditures or the numbers of technical people employed (e.g., scientists, engineers, technicians) with industry value added or the total value of its shipments. In this chapter, high-technology industries are identified using R&D intensities calculated by the Organisation for Economic Co-operation and Development.

[4]In designating these high-technology industries, OECD took into account both direct and indirect R&D intensities for 10 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, the Netherlands, Denmark, and Australia. Direct intensities were calculated by the ratio of R&D expenditure to output (production) in 22 industrial sectors. Each sector was given a weight according to its share in the total output of the 10 countries using purchasing power parities as exchange rates. Indirect intensity calculations were made using technical coefficients of industries on the basis of input-output matrices. OECD then assumed that, for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (1993).

The Importance of High-Technology Industries

The global market for high-technology goods is growing at a faster rate than that for other manufactured goods, and high-technology industries are driving economic growth around the world.[5] During the 19-year period examined (1980–98), high-technology production grew at an inflation-adjusted average annual rate of nearly 6.0 percent compared with 2.7 percent for other manufactured goods.[6] Global economic activity was especially strong at the end of the period (1995–98), when high-technology industry output grew at 13.9 percent per year, more than three times the rate of growth for all other manufacturing industries. (See figure 6-1 and appendix table 6-1.) Output by the four high-technology industries, those identified as being the most research intensive, represented 7.6 percent of global production of all manufactured goods in 1980; by 1998, this figure rose to 12.7 percent.

During the 1980s, the United States and other high-wage countries devoted increasing resources toward the manufacture of higher value, technology-intensive goods, often referred to as "high-technology manufactures." During this period, Japan led the major industrialized countries in its concentration on high-technology manufactures. In 1980, high-technology manufactures accounted for about 8 percent of total Japanese production, approaching 11 percent in 1984 and increasing to 11.6 percent in 1989. By contrast, high-technology manufactures represented nearly 11 percent of total U.S. production in 1989, up from 9.6 percent in 1980. European nations also saw high-technology manufactures account for a growing share of their total production, although to a lesser degree than seen in the United States and Japan. The one exception was the United Kingdom, where high-technology manufactures rose from 9 percent of total manufacturing output in 1980 to nearly 11 percent by 1989.

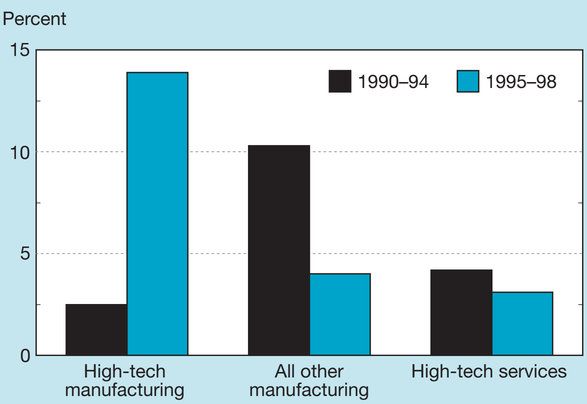
The major industrialized countries continued to emphasize high-technology manufactures into the 1990s. (See figure 6-2.) In 1998, high-technology manufactures were estimated at 16.6 percent of manufacturing output in the United States, 16.0 percent in Japan, 14.9 percent in the United Kingdom, 11.0 percent in France, and 9.0 percent in Germany.

Taiwan and South Korea typify how important R&D-intensive industries have become to newly industrialized economies. In 1980, high-technology manufactures accounted for less than 12 percent of Taiwan's total manufacturing output; this proportion jumped to 16.7 percent in 1989 and reached 25.6 percent in 1998. In 1998, high-technology manufacturing in South Korea (15.0 percent) accounted for about the same percentage of total output as in the United Kingdom (14.9 percent) and almost twice the percentage of total manufacturing output as in Germany (9.0 percent).

[5]This section is based on data reported by WEFA (2000) in its World Industry Service database. This database provides production data for 68 countries and accounts for more than 97 percent of global economic activity.

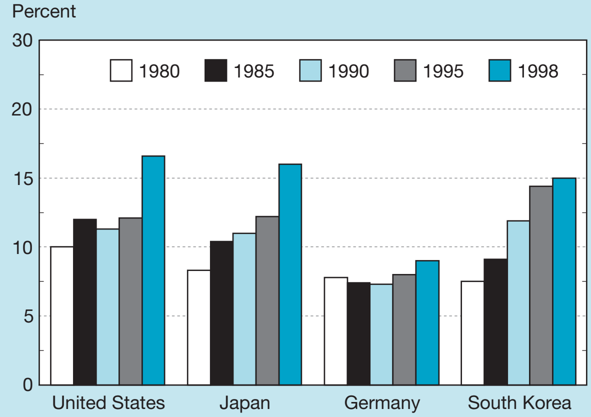
[6]Service-sector industries grew at an inflation-adjusted average annual rate of 3.5 percent during this period.

Figure 6-1.
Global industry sales, average growth rate, by sector



See appendix table 6-1. *Science & Engineering Indicators – 2002*

Figure 6-2.
High-tech industries' share of total manufacturing output



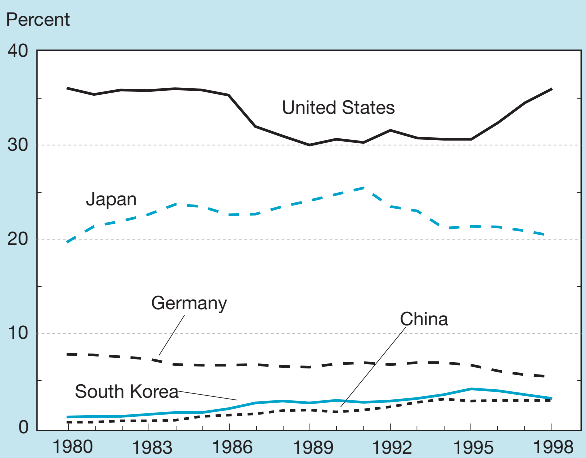
See appendix table 6-1. *Science & Engineering Indicators – 2002*

Share of World Markets

Throughout the 1980s, the United States was the world's leading producer of high-technology products, responsible for more than one-third of total world production from 1980 to 1987 and for about 30 percent from 1988 to 1995. U.S. world market share began to rise in 1996 and continued moving upward during the following two years. (See figure 6-3.) In 1998, the United States high-technology industry accounted for 36 percent of world high-technology production, a level last reached in the 1980s.

Although the United States struggled to maintain its high-technology market share during the 1980s, Asia's market share followed a path of steady gains. In 1989, Japan accounted for 24 percent of the world's production of high-technology products, moving up 4 percentage points from its 1980 share. Japan continued to gain market share through 1991. Since then,

Figure 6-3.
Country share of global high-tech market: 1980–98



See appendix table 6-1. *Science & Engineering Indicators – 2002*

however, Japan's market share has dropped steadily, falling to 20 percent of world production in 1998 after accounting for nearly 26 percent in 1991.

European nations' share of world high-technology production is much lower and has been declining. Germany's share of world high-technology production was about 8 percent in 1980, about 6.4 percent in 1989, and 5.4 percent in 1998. The United Kingdom's high-technology industry produced 6.7 percent of world output in 1980, dropping to about 6.0 percent in 1989 and 5.4 percent in 1998. In 1980, French high-technology industry produced 6.1 percent of world output; it dropped to 5.3 percent in 1989 and 3.9 percent in 1998. Italy's shares were the lowest among the four large European economies, ranging from a high of about 2.7 percent of world high-technology production in 1980 to a low of about 1.6 percent in 1998.

Developing Asian nations made the most dramatic gains since 1980. South Korea's market share more than doubled during the 1980s, moving from 1.1 percent in 1980 to 2.6 percent in 1989. South Korea's share continued to increase during the early to mid-1990s, peaking at 4.1 percent in 1995. Since 1995, South Korea's market share has dropped each year, falling to 3.1 percent in 1998. Taiwan's high-technology industry also gained world market share during the 1980s and early 1990s before leveling off in the later 1990s. Taiwan's high-technology industry produced just 1.3 percent of the world's output in 1980. This figure rose to 2.4 percent in 1989 and leveled off at 3.3 percent in 1997 and 1998.

Global Competitiveness of Individual Industries

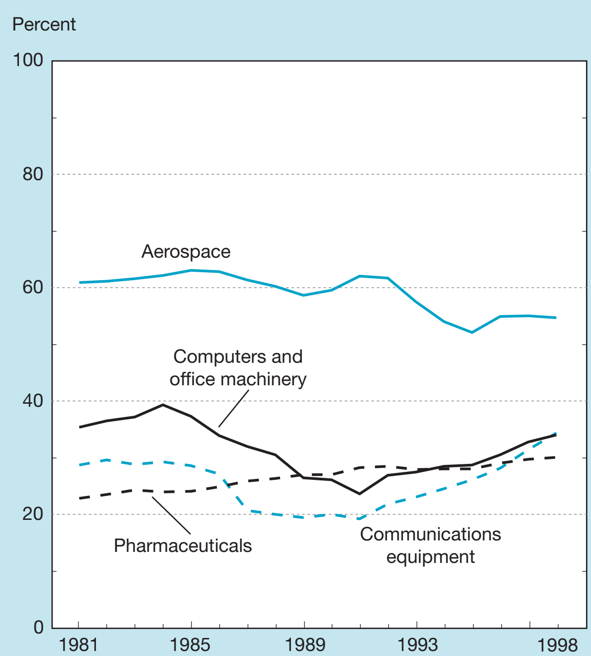
In each of the four industries that make up the high-technology group, the United States maintained strong, if not leading, market positions between 1981 and 1998. Competitive pressures from a growing cadre of high-technology-producing nations contributed to a decline in global market share for two U.S. high-technology industries during the 1980s: computers and office machinery and communications equipment. Both of these U.S. industries reversed their downward trends and gained market share in the mid- to late 1990s, thanks to increased capital investment by U.S. businesses.[7] (See figure 6-4.)

For most of the 19-year period examined, Japan was the world's leading supplier of communications equipment, representing about one-third of total world output. Japan's production surpassed that of the United States in 1981 and held the top position for the next 14 years. In 1995, U.S. manufacturers once again became the leading producer of communications equipment in the world, and they have retained that position ever since. In 1998, the latest year for which data are available, the United States accounted for 34.4 percent of world production of communications equipment, up from 31.5 percent in 1997.

Aerospace, the U.S. high-technology industry with the largest world market share, was the only industry to lose market share in both the 1980s and the 1990s. For most of the 1980s, the U.S. aerospace industry supplied more than 60 percent of world demand. By the late 1980s, the U.S. share of the world aerospace market began an erratic decline, falling to 58.9 percent in 1989 and 52.1 percent by 1995. The United States recovered somewhat during the following three years, supplying about 55 percent of the world market from 1996 to 1998. European aerospace industries, particularly the British

[7]These data are discussed in chapter 8.

Figure 6-4.
U.S. global market share, by high-tech industry: 1981–98



See appendix table 6-1. *Science & Engineering Indicators – 2002*

aerospace industry, made some gains during the period examined. After fluctuating between 8.5 and 10.5 percent during the 1980s, the United Kingdom's industry slowly gained market share for much of the 1990s. In 1991, the United Kingdom supplied 9.7 percent of world aircraft shipments; by 1998, its share had increased to 13 percent.

Of the four U.S. high-technology industries, only the aerospace and pharmaceutical industries managed to retain their number-one rankings throughout the 19-year period; of these two, only the pharmaceutical industry had a larger share of the global market in 1998 than in 1980.

The United States is considered a large, open market. These characteristics benefit U.S. high-technology producers in two important ways. First, supplying a market with many domestic consumers provides scale effects to U.S. producers in the form of potentially large rewards for the production of new ideas and innovations (Romer 1996). Second, the openness of the U.S. market to competing foreign-made technologies pressures U.S. producers to be inventive and more innovative to maintain domestic market share.

Exports by High-Technology Industries

Although U.S. producers benefit from having the world's largest home market as measured by gross domestic product (GDP), mounting trade deficits highlight the need to serve foreign markets as well. U.S. high-technology industries have traditionally been more successful exporters than other U.S. industries and play a key role in returning the United States to a more balanced trade position.

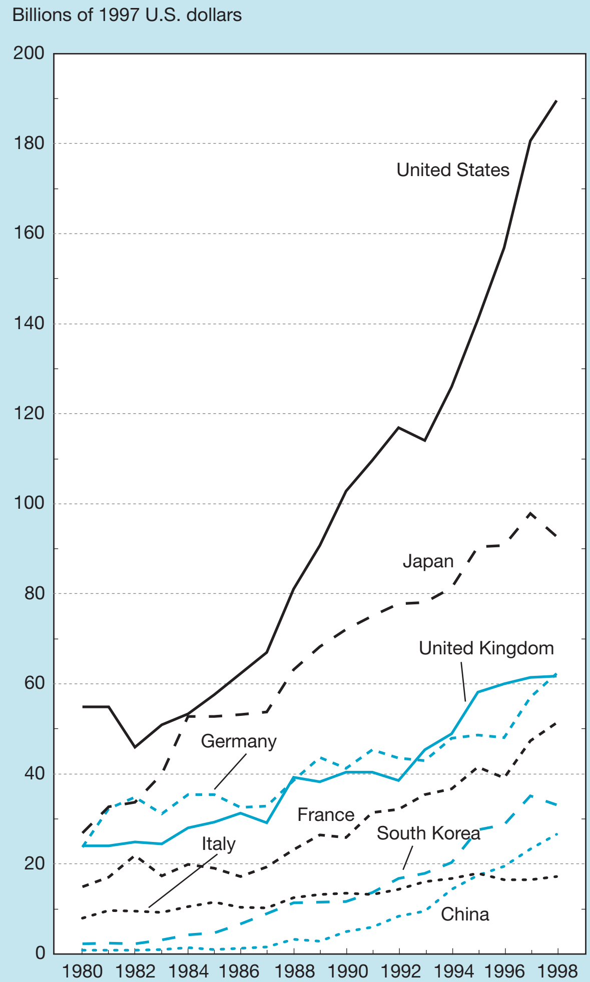
Foreign Markets

Despite its domestic focus, the United States was an important supplier of manufactured products to foreign markets throughout the 1980–98 period. From 1993 to 1998, the United States was the leading exporter of manufactured goods, accounting for about 13 percent of world exports.

U.S. high-technology industries contributed to the strong export performance of the nation's manufacturing industries. (See figure 6-5 and appendix table 6-1.) During the same 19-year period, U.S. high-technology industries accounted for between 19 and 26 percent of world high-technology exports, which was at times twice the level achieved by all U.S. manufacturing industries. In 1998, the latest year for which data are available, exports by U.S. high-technology industries accounted for 19.8 percent of world high-technology exports; Japan was second with 9.7 percent, followed by Germany with 6.5 percent.

The gradual drop in U.S. share during the 19-year period was in part the result of emerging high-technology industries in newly industrialized economies, especially in Asia. In 1980, high-technology industries in Singapore and Taiwan each accounted for about 2.0 percent of world high-technology exports. The latest data for 1998 show Singapore's share reaching 6.4 percent and Taiwan's share reaching 5.0 percent.

Figure 6-5.
High-tech exports: 1980–98



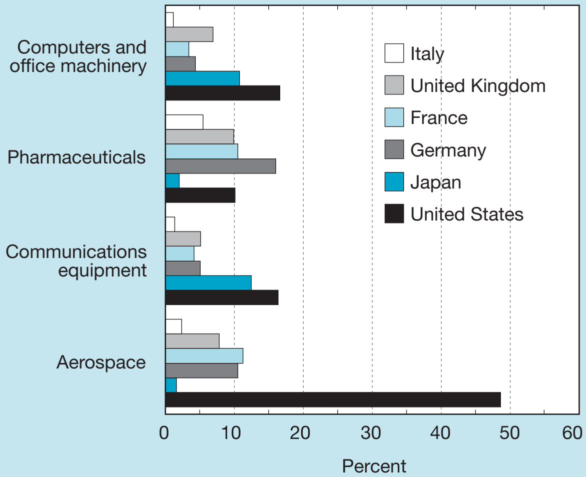
See appendix table 6-1. *Science & Engineering Indicators – 2002*

Industry Comparisons

Throughout the 19-year period, individual U.S. high-technology industries ranked either first or second in exports in each of the four industries that make up the high-technology group. In 1998, the United States was the export leader in three industries and second in only one, pharmaceuticals. (See figure 6-6.)

U.S. industries producing aerospace technologies, computers and office machinery, and pharmaceuticals all accounted for smaller shares of world exports in 1998 than in 1980; only the communications equipment industry improved its share during the period. By contrast, Japan's share of world exports of communications equipment dropped steadily after 1985, eventually falling to 12.5 percent by 1998 from a high of 36.0 percent just 13 years earlier. Several smaller Asian nations fared better: for example, in 1998, South Korea supplied 5.9 percent of world communication product exports, up from just 2.4 percent in 1980, and Singapore supplied 10.6 percent of world office and computer exports in 1998, up from 0.6 percent in 1980.

Figure 6-6.
Export market share in high-tech industries: 1998



See appendix table 6-1. *Science & Engineering Indicators – 2002*

Competition in the Home Market

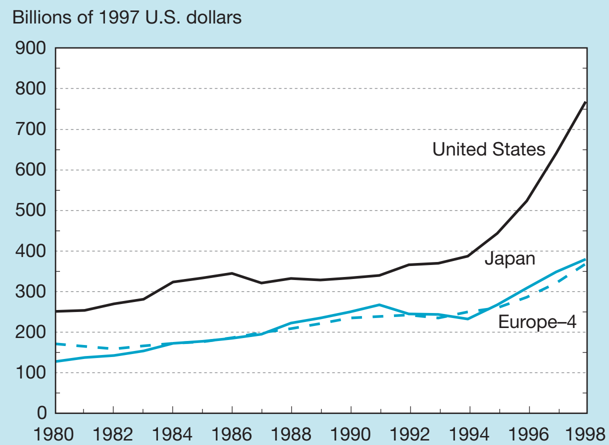
A country's home market is often considered the natural destination for the goods and services domestic firms have produced. Proximity to the customer as well as common language, customs, and currency make marketing at home easier than marketing abroad.

With trade barriers falling, however, product origin may be only one factor among many influencing consumer choice. As the number of firms producing goods to world standards rises, price, quality, and product performance often become equally or more important criteria for selecting products. Thus, in the absence of trade barriers, the intensity of competition faced by producers in the domestic market can approach and, in some markets, exceed that faced in foreign markets. U.S. competitiveness in foreign markets may be the result of two factors: the existence of tremendous domestic demand for the latest technology products and the pressure of global competition, which spurs innovation.

National Demand for High-Technology Products

Demand for high-technology products in the United States far exceeds that in any other single country; in 1998, it was larger (approximately $768 billion) than the combined markets of Japan and the four largest European nations—Germany, the United Kingdom, France, and Italy (about $749 billion). (See figure 6-7.) In 1991, Japan was the world's second largest market for high-technology products, although its percentage share of world consumption has generally declined since then. Even though economic problems across much of Asia have curtailed a long period of rapid growth, Asia continues to be a large market for the world's high-technology exports.

Figure 6-7.
National apparent consumption[1] of high-tech products: 1980–98



[1]Apparent consumption equals gross output plus imports minus exports corrected for implied service costs associated with export sales.

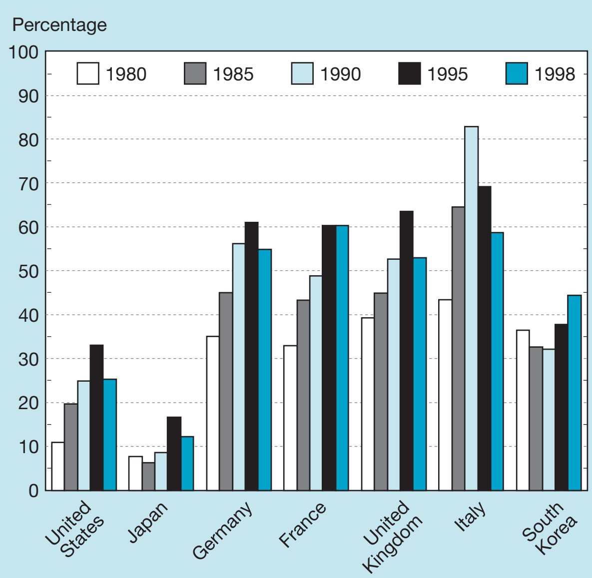
NOTE: Europe–4 refers to the four largest European economies: Germany, France, the United Kingdom, and Italy.

See appendix table 6-1. *Science & Engineering Indicators – 2002*

National Producers Supplying the Home Market

Throughout the 1980–95 period, the world's largest market for high-technology products, the United States, was served primarily by domestic producers, yet demand was increasingly met by a growing number of foreign suppliers. (See figure 6-8.) In 1998, U.S. producers supplied about 75 percent of the home market for high-technology products; in 1995, their share was much lower—about 67 percent.

Figure 6-8.
Import share of domestic high-tech markets



See appendix table 6-1. *Science & Engineering Indicators – 2002*

Other countries, particularly those in Europe, have experienced increased foreign competition in their domestic markets. A more economically unified market has made Europe especially attractive to the rest of the world. Rapidly rising import penetration ratios in Germany, the United Kingdom, France, and Italy during the latter part of the 1980s and throughout much of the 1990s reflect these changing circumstances. These data also highlight greater trade activity in European high-technology markets compared with product markets for less technology-intensive manufactures.

The Japanese home market, the second largest market for high-technology products and historically the most self-reliant of the major industrialized countries, also increased its purchases of foreign technologies over the 19-year period, although slowly. In 1998, imports of high-technology manufactures supplied about 12 percent of Japanese domestic consumption, up from about 7 percent in 1980.

Global Business in Knowledge-Intensive Service Industries

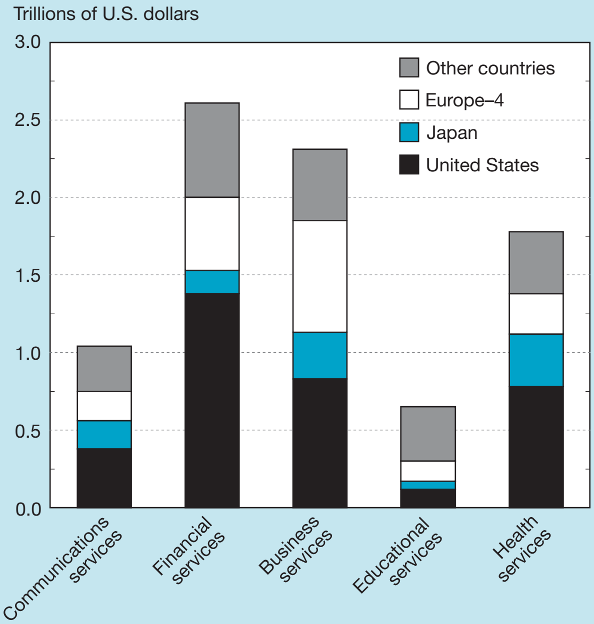
For several decades, revenues generated by U.S. service-sector industries have grown faster than those generated by the nation's manufacturing industries. Data collected by the Department of Commerce show that the service sector's share of the U.S. GDP grew from 49 percent in 1959 to 64 percent in 1997 (National Science Board 2000; appendix table 9-4). Service-sector growth has been fueled largely by "knowledge-intensive" industries—those incorporating science, engineering, and technology in their services or in the delivery of those services. Five of these knowledge-intensive industries are communications services, financial services, business services (including computer software development), educational services, and health services. These industries have been growing faster than the high-technology manufacturing sector discussed earlier. This section presents data tracking overall revenues earned by these industries in 68 countries.[8] (See figure 6-9 and appendix table 6-2.)

Combined sales in 1997 dollars in these five service-sector industries approached $8.4 trillion in 1998, up from $6.8 trillion in 1990 and $4.8 trillion in 1980. The United States was the leading provider of high-technology services, responsible for between 38 and 41 percent of total world service revenues during the entire 19-year period examined.

The financial services industry is the largest of the five service industries examined, accounting for 31 percent of revenues in 1998. The U.S. financial services industry is the world's largest, with 52.9 percent of world revenues in 1998. Japan was second at 5.9 percent, followed by Germany at 4.1 percent.

Business services, which includes computer and data processing and research and engineering services, is the second largest service sector, accounting for nearly 28 percent of revenues in 1998. The U.S. business services industry is the largest in the world, with 36.0 percent of industry revenues in

Figure 6-9.
Global revenues generated by five knowledge-intensive service industries: 1998



NOTE: Europe–4 refers to the four largest European economies: Germany, France, the United Kingdom, and Italy.

See appendix table 6-2. *Science & Engineering Indicators – 2002*

1998. France is second with 17.1 percent, followed by Japan with 12.9 percent and the United Kingdom with 6.1 percent. Unfortunately, data on individual business services by country are not available.

Communications services, which includes telecommunications and broadcast services, is the fourth-largest service industry examined, accounting for 12.3 percent of revenues in 1998. In what many consider the most technology-driven of the service industries, the United States has the dominant position. In 1998, U.S. communications firms generated revenues that accounted for 36.8 percent of world revenues, more than twice the share held by Japanese firms and six times that held by British firms.

Because in many nations the government is the primary provider of the remaining two knowledge-intensive service industries (health services and educational services), and because the size of a country's population affects the delivery of these services, global comparisons are more difficult and less meaningful than those for other service industries. The United States, with the largest population and least government involvement, has the largest commercial industries in the world in both health services and educational services. Japan is second, followed by Germany. Educational services, the smallest of the five knowledge-intensive service industries, had about one-fourth of the revenues generated by the financial services industry worldwide.

[8]Unlike those for manufacturing industries, national data that track activity in many of the hot new service sectors are limited in the level of industry disaggregation available and the types of activity for which national data are collected.

U.S. Trade Balance in Technology Products

Although no single preferred methodology exists for identifying high-technology industries, most calculations rely on a comparison of R&D intensities. R&D intensity, in turn, is typically determined by comparing industry R&D expenditures or the number of technical people employed (e.g., scientists, engineers, and technicians) with industry value added or the total value of its shipments.[9] Classification systems based on R&D intensity, however, are often distorted by including all products produced by particular high-technology industries, regardless of the level of technology embodied in each product, and by the somewhat subjective process of assigning products to specific industries. In contrast, the classification system discussed here allows for a highly disaggregated, more focused examination of technology embodied in traded goods. To minimize the impact of subjective classification, the judgments offered by government experts are reviewed by other experts.

The Bureau of the Census has developed a classification system for exports and imports that embody new or leading-edge technologies. This classification system allows trade to be examined in 10 major technology areas:

- **Biotechnology**—the medical and industrial application of advanced genetic research to the creation of drugs, hormones, and other therapeutic items for both agricultural and human uses.
- **Life science technologies**—the application of nonbiological scientific advances to medicine. For example, advances such as nuclear magnetic resonance imaging, echocardiography, and novel chemistry, coupled with new drug manufacturing, have led to new products that help control or eradicate disease.
- **Opto-electronics**—the development of electronics and electronic components that emit or detect light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers.
- **Information and communications**—the development of products that process increasing amounts of information in shorter periods of time, including fax machines, telephone switching apparatus, radar apparatus, communications satellites, central processing units, and peripheral units such as disk drives, control units, modems, and computer software.
- **Electronics**—the development of electronic components (other than opto-electronic components), including integrated circuits, multilayer printed circuit boards, and surface-mounted components, such as capacitors and resistors, that result in improved performance and capacity and, in many cases, reduced size.
- **Flexible manufacturing**—the development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles, that permit greater flexibility in the manufacturing process and reduce human intervention.
- **Advanced materials**—the development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance the application of other advanced technologies.
- **Aerospace**—the development of aircraft technologies, such as most new military and civil airplanes, helicopters, spacecraft (with the exception of communication satellites), turbojet aircraft engines, flight simulators, and automatic pilots.
- **Weapons**—the development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms.
- **Nuclear technology**—the development of nuclear production apparatus, including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges (nuclear medical apparatus is included in life sciences rather than this category).

To be included in a category, a product must contain a significant amount of one of the leading-edge technologies, and the technology must account for a significant portion of the product's value.

Importance of Advanced Technology Product Trade to Overall U.S. Trade

Advanced technology products accounted for an increasing share of all U.S. trade (exports plus imports) in merchandise between 1990 and 1999. (See text table 6-1 and appendix table 6-3.) Total U.S. trade in merchandise exceeded $1.7 trillion in 1999; of that, $381 billion involved trade in advanced technology products. Trade in advanced technology products accounts for a much larger share of U.S. exports than of imports (29.2 percent versus 17.5 percent in 1999) and makes a positive contribution to the overall balance of trade. After several years in which the surplus generated by trade in advanced technology products declined, exports of U.S. advanced technology products outpaced imports in 1996 and 1997, producing larger surpluses in both years. In 1998 and 1999, the economic slowdown in Asia caused declines in exports and in the surplus generated from U.S. trade in advanced technology products.

Technologies Generating Trade Surpluses

Throughout the 1990s, U.S. exports of advanced technology products exceeded imports in 8 of 11 technology areas.[10] Trade in aerospace technologies consistently produced the largest surpluses for the United States. Those surpluses narrowed in the mid-1990s as competition from Europe's aerospace industry challenged U.S. companies' preeminence both

[9] See footnote 2 for a discussion of the methodology.

[10] Software products is not a separate advanced technology products category; it is included in the category covering information and communications products. To better examine this important technology area, software products was broken out from the information and communications, creating an 11th category.

Text table 6-1.
U.S. international trade in merchandise

Type of trade	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total trade (billions of U.S.$)	888.3	910.0	979.9	1,045.3	1,176.2	1,325.3	1,410.8	1,556.1	1,587.5	1,714.3
Technology products (%)	17.3	18.1	18.3	18.1	18.6	19.9	20.2	21.0	21.6	22.2
Other merchandise (%)	82.7	81.9	81.7	81.9	81.4	80.1	79.8	79.0	78.4	77.8
Total exports (billions of U.S.$)	393.0	421.9	447.5	464.8	512.4	575.9	611.5	679.7	670.3	684.4
Technology products (%)	24.1	24.1	23.9	23.3	23.6	24.0	25.3	26.4	27.8	29.2
Other merchandise (%)	75.9	75.9	76.1	76.7	76.4	76.0	74.7	73.6	72.2	70.8
Total imports (billions of U.S.$)	495.3	488.1	532.4	580.5	663.8	749.4	799.3	876.4	917.2	1,029.9
Technology products (%)	12.0	13.0	13.5	14.0	14.8	16.7	16.3	16.8	17.1	17.5
Other merchandise (%)	88.0	87.0	86.5	86.0	85.2	83.3	83.7	83.2	82.9	82.5

NOTE: Total trade is the sum of total exports and total imports.

SOURCE: U.S. Bureau of the Census, Foreign Trade Division (2001). Available at <http://www.fedstats.gov>, March 2001.

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at home and in foreign markets. Aerospace technologies generated a net inflow of $25 billion in 1990 and nearly $29 billion in 1991 and 1992; trade surpluses then declined 13 percent in 1993, 9 percent in 1994, and 4 percent in 1995. In 1998, U.S. trade in aerospace technologies produced a net inflow of $39 billion, the largest surplus of the decade, and 1999's surplus was only slightly smaller at $37 billion. Trade is more balanced in five other technology areas (biotechnology, flexible manufacturing technologies, advanced materials, weapons, and nuclear technology), with exports having only a slight edge over imports. Each of these areas showed trade surpluses of less than $3 billion in 1999.

Although U.S. imports of electronics technologies exceeded exports for much of the decade, 1997 saw U.S. exports of electronics exceed imports by $1.1 billion, which jumped to $4.2 billion in 1998 and $9.4 billion in 1999. This turnaround may be attributed in part to Asia's economic problems in 1998 and a stronger U.S. dollar, which may have reduced the number of electronics products imported from Asia in 1998. Imports from Asia recovered to pre-1998 levels in 1999, with the largest jumps in imports coming not from Japan but from South Korea, the Philippines, and Malaysia.

Technologies Generating Trade Deficits

In 1999, trade deficits were recorded in three technology areas: information and communications, opto-electronics, and life science technologies. The trends for each of these technology areas are quite different. Only opto-electronics showed trade deficits in each of the 10 years examined. U.S. trade in life science technologies consistently generated annual trade surpluses until 1998. Life science exports were virtually flat in the last two years of the decade, while imports jumped 24 percent in 1998 and 21 percent in 1999. Interestingly, in a technology area in which the United States is considered to be at the forefront (information and communications), annual U.S. imports have consistently exceeded exports since 1992. Nearly three-fourths of all U.S. imports in this technology area are produced in Asia.[11]

[11]The Bureau of the Census is not able to identify the degree to which this trade is between affiliated U.S. and foreign companies.

Top Customers by Technology Area

Japan and Canada are the largest customers for a broad range of U.S. technology products, with each country accounting for about 11 percent of total U.S. technology exports. Japan ranks among the top three customers in 9 of 11 technology areas, Canada in 7. (See figure 6-10 and appendix table 6-4.) European countries are also important consumers of U.S. technology products, particularly Germany (life science products, opto-electronics, and advanced materials), the United Kingdom (aerospace, weapons, and computer software), and the Netherlands (life science products and weapons).

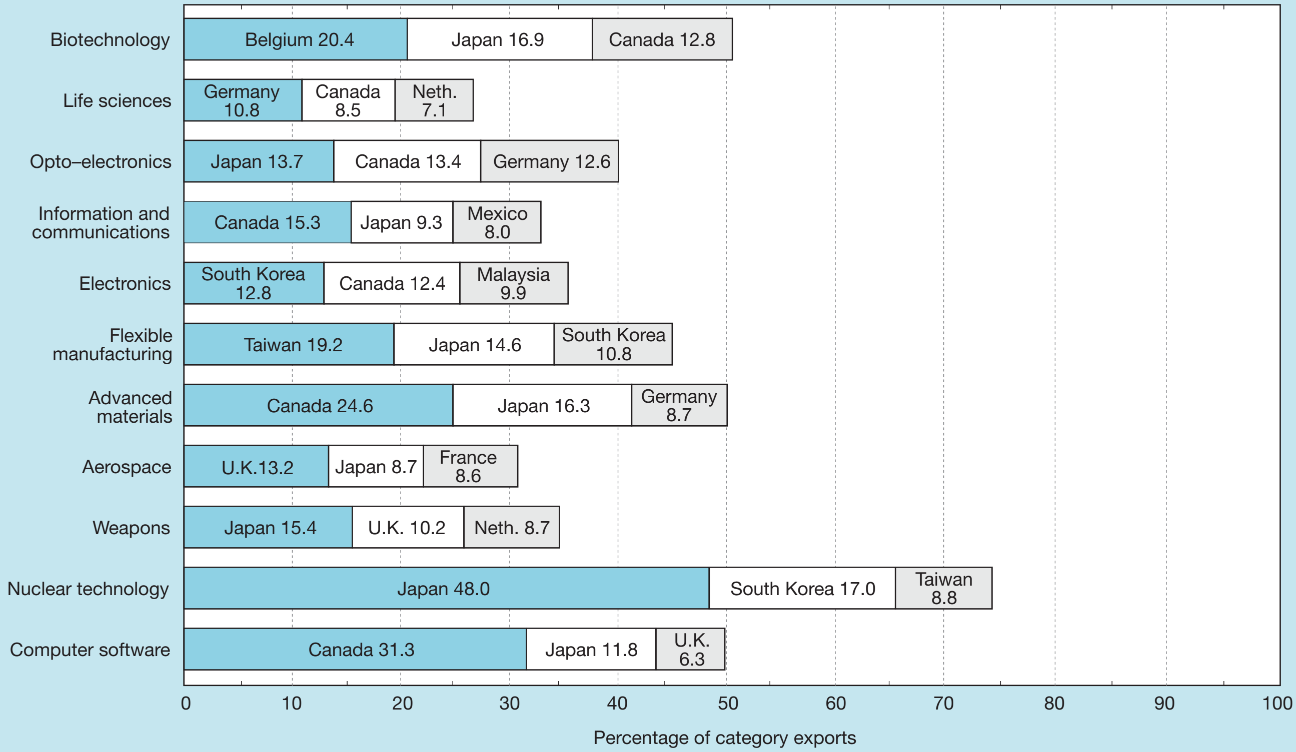
Although Europe, Japan, and Canada have long been important consumers of U.S. technology products, several newly industrialized and emerging Asian economies now also rank among the largest customers. South Korea is a leading consumer in three technology areas (electronics, flexible manufacturing, and nuclear technologies) and Taiwan in two (flexible manufacturing and nuclear technologies).

Top Suppliers by Technology Area

The United States is not only an important exporter of technologies to the world but also a consumer of imported technologies. The leading economies in Asia and Europe are important suppliers to the U.S. market in each of the 11 technology areas. (See figure 6-11 and appendix table 6-5.) Japan is a major supplier in six advanced technology categories; Canada, France, Germany, Taiwan, and the United Kingdom in three. Smaller European countries are also major suppliers of technology to the United States, although they tend to specialize. Belgium was the top foreign supplier of biotechnology products to the United States in 1999, the source for 25.5 percent of imports in this category. Switzerland also was among the top three suppliers of biotechnology products with 11.3 percent.

Many technology products come from developing Asian economies, especially Malaysia, South Korea, and Singapore. Imports from these Asian economies and from other regions into one of the world's most demanding markets indicate that technological capabilities are expanding globally.

Figure 6-10.
Three largest export markets for U.S. technology products: 1999



See appendix table 6-4. *Science & Engineering Indicators – 2002*

U.S. Royalties and Fees Generated From Intellectual Property

The United States has traditionally maintained a large trade surplus in intellectual property. Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. These transactions generate net revenues in the form of royalties and licensing fees.

U.S. Royalties and Fees From All Transactions

Total U.S. receipts from all trade in intellectual property more than doubled between 1990 and 1999, reaching nearly $36.5 billion in 1999. (See appendix table 6-6.) During the 1987–96 period, U.S. receipts for transactions involving intellectual property were generally four to five times larger than U.S. payments to foreign firms. The gap narrowed in 1997 as U.S. payments increased by 20 percent over the previous year and U.S. receipts rose less than 3 percent. Despite the much larger increase in payments, annual receipts from total U.S. trade in intellectual property in 1997 were still more than 3.5 times greater than payments. This trend continued during the following two years, and by 1999, the ratio of receipts to payments had dropped to about 2.7:1.

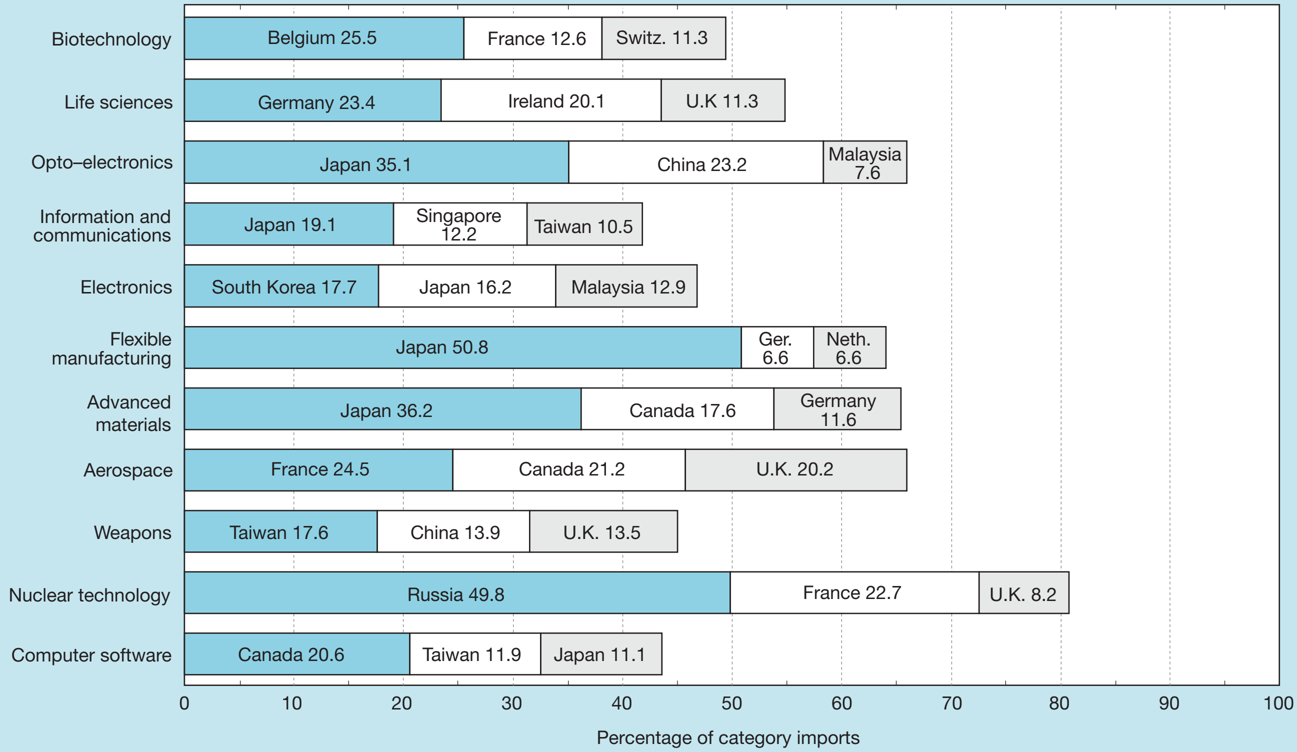
U.S. trade in intellectual property produced a surplus of $23.2 billion in 1999, down slightly from the nearly $24.5 billion surplus recorded a year earlier. (See figure 6-12.) About 75 percent of the transactions involved exchanges of intellectual property between U.S. firms and their foreign affiliates.[12] Exchanges of intellectual property among affiliates have grown at about the same pace as those among unaffiliated firms, except during the late 1990s, when the growth in U.S. firm payments to affiliates exceeded receipts. These trends suggest both a growing internationalization of U.S. business and a growing reliance on intellectual property developed overseas.

U.S. Royalties and Fees From Trade in Technical Knowledge

Data on royalties and fees generated by trade in intellectual property can be further disaggregated to reveal U.S. trade in technical know-how. The following data describe transactions between unaffiliated firms where prices are set through a market-based negotiation. Therefore, they may better reflect the exchange of technical know-how and its market value at a given time than do data on exchanges among affiliated firms. When receipts (sales of technical know-how) consistently exceed payments (purchases), these data may indicate a comparative advantage in the creation of industrial technology. The record of

[12]An *affiliate* refers to a business enterprise located in one country that is directly or indirectly owned or controlled by an entity of another country. The controlling interest for an incorporated business is 10 percent or more of its voting stock; for an unincorporated business, it is an interest equivalent to 10 percent of voting stock.

Figure 6-11.
Top three foreign suppliers of technology products to the United States: 1999



See appendix table 6-5. *Science & Engineering Indicators – 2002*

resulting receipts and payments also provides an indicator of the production and diffusion of technical knowledge.

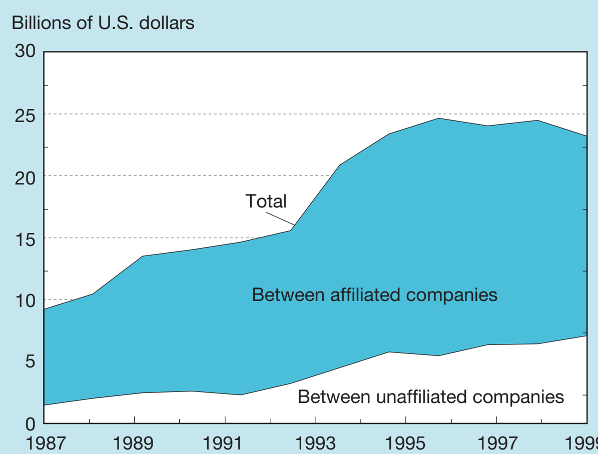
The United States is a net exporter of technology sold as intellectual property, although the gap between imports and exports narrowed during the late 1990s. During the first half of the 1990s, royalties and fees received from foreign firms have been an average of three times the amount U.S. firms pay foreigners to access their technology. Between 1996 and 1998, receipts plateaued at about $3.5 billion. In 1999, receipts totaled nearly $3.6 billion, little changed from the year before but still more than double that reported for 1987. (See figure 6-13 and appendix table 6-7.)

Japan is the world's largest consumer of U.S. technology sold as intellectual property, although its share declined significantly during the 1990s. In 1999, Japan accounted for about 30 percent of all such receipts. At its peak in 1993, Japan's share was 51 percent.

Another Asian country, South Korea, is the second largest consumer of U.S. technology sold as intellectual property, accounting for nearly 14 percent of U.S. receipts in 1999. South Korea has been a major consumer of U.S. technological know-how since 1988, when it accounted for 5.5 percent of U.S. receipts. South Korea's share rose to 10.7 percent in 1990 and reached its highest level, 17.3 percent, in 1995.

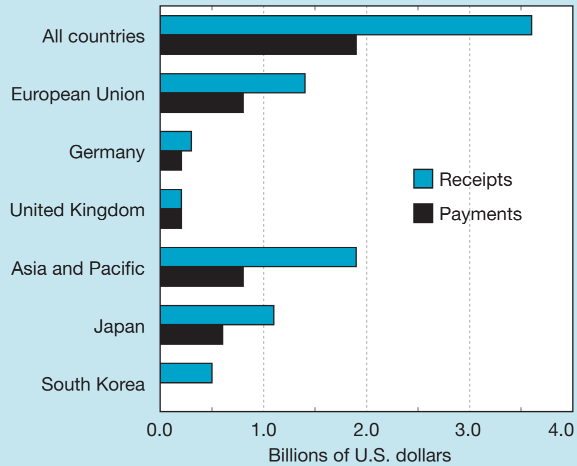
The U.S. trade surplus in intellectual property is driven largely by trade with Asia, but that surplus has narrowed recently. In 1995, U.S. receipts (exports) from technology licensing transactions were nearly seven times the U.S. firm payments (imports) to Asia. That ratio closed to just more than 4:1 by 1997, and the most recent data show U.S. receipts from technology licensing transactions at about 2.5 times the U.S. firm payments to Asia. As previously noted, Japan and South Korea were the biggest customers for U.S. technology sold as intellectual property; together, these countries ac-

Figure 6-12.
U.S. trade balance of royalties and fees: 1987–99



See appendix table 6-6. *Science & Engineering Indicators – 2002*

Figure 6-13.
U.S. royalties and fees generated from the exchange of industrial processes between unaffiliated companies: 1999



See appendix table 6-7. *Science & Engineering Indicators – 2002*

counted for more than 44 percent of total receipts in 1999.

Until 1994, U.S. trade with Europe in intellectual property, unlike trade with Asia, fluctuated between surplus and deficit. In 1994, a sharp decline in U.S. purchases of European technical know-how led to a considerably larger surplus for the United States compared with earlier years. The following year showed another large surplus resulting from a jump in receipts from the larger European countries. In 1999, receipts from European Union (EU) countries represented about 35 percent of U.S. technology sold as intellectual property, more than double the share in 1993. Some of this increase is attributable to increased licensing by firms in Germany, the third largest consumer of U.S. technological know-how. In 1999, Germany's share rose to 9.3 percent, up from 6.9 percent in 1998 and more than double its share in 1993. These latest data show receipts from France and Sweden rising sharply during the late 1990s, causing a considerably larger surplus from U.S. trade with Europe in intellectual property in 1998 and 1999.

U.S. firms have purchased technical know-how from different foreign sources over the years, with increasing amounts coming from Japan, which since 1992 has been the single largest foreign supplier of technical know-how to U.S. firms. About one-third of U.S. payments in 1999 for technology sold as intellectual property were made to Japanese firms. Europe accounts for slightly more than 44 percent of the foreign technical know-how purchased by U.S. firms; the United Kingdom and Germany are the principal European suppliers.[13]

[13]Over the years, France has also been an important source of technological know-how. In 1996, France was the leading European supplier to U.S. firms. Since then, data on France have been suppressed to avoid disclosing individual company operations.

[14]See chapter 2 for the discussion of international higher education trends and chapter 4 for the discussion of trends in international R&D.

New High-Technology Exporters

Several nations have made tremendous technological leaps forward over the past decade. Some of these countries are well positioned to play more important roles in technology development because of their large and continuing investments in S&E education and R&D.[14] However, their success may hinge on other factors as well, including political stability, access to capital, and an infrastructure that can support technological and economic advancement.

This section assesses a group of selected countries and their potential to become more important exporters of high-technology products during the next 15 years, based on the following leading indicators:

- **National orientation**—evidence that a nation is taking action to become technologically competitive, as indicated by explicit or implicit national strategies involving cooperation between the public and private sectors.
- **Socioeconomic infrastructure**—the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to the functioning of a modern, technology-based industrial nation. Indicators include the existence of dynamic capital markets, upward trends in capital formation, rising levels of foreign investment, and national investments in education.
- **Technological infrastructure**—the social and economic institutions that contribute directly to a nation's ability to develop, produce, and market new technology. Indicators include the existence of a system for the protection of intellectual property rights (IPR), the extent to which R&D activities relate to industrial application, competency in high-technology manufacturing, and the capability to produce qualified scientists and engineers.
- **Productive capacity**—the physical and human resources devoted to manufacturing products and the efficiency with which those resources are used. Indicators include the current level of high-technology production, the quality and productivity of the labor force, the presence of skilled labor, and the existence of innovative management practices.

This section analyzes 15 economies: 6 in Asia (China, India, Indonesia, Malaysia, the Philippines, and Thailand); 3 in Central Europe (Czech Republic, Hungary, and Poland); 4 in Latin America (Argentina, Brazil, Mexico, and Venezuela); and 2 others (Ireland and Israel) that have shown increased technological activity.[15]

National Orientation

The national orientation indicator identifies nations whose businesses, government, and culture encourage high-technology development. This indicator was constructed using information from a survey of international experts and published

[15]See Porter and Roessner (1991) for details on survey and indicator construction; see Roessner, Porter, and Xu (1992) for information on the validity and reliability testing the indicators have undergone.

data. The survey asked the experts to rate national strategies that promote high-technology development, social influences favoring technological change, and entrepreneurial spirit. Published data were used to rate each nation's risk factor for foreign investment during the next five years (PRS Group 1999).

Ireland and Israel posted the highest overall scores by far on this indicator. (See figure 6-14 and appendix table 6-8.) Although Ireland scored slightly lower than Israel on each of the expert-opinion components, its rating as a much safer place for foreign investment than Israel elevated its composite score.

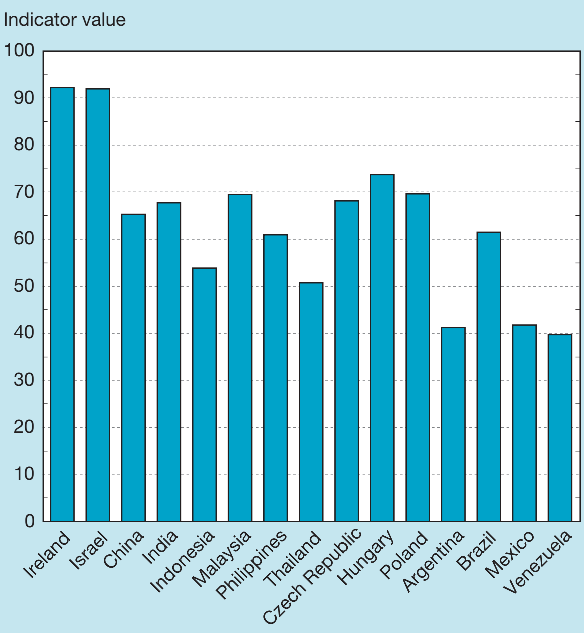
The national orientation of both Ireland and Israel was scored consistently and significantly higher than that of the other countries examined and was well within the range of scores accorded the more advanced economies of Taiwan and Singapore. Hungary, Poland, and Malaysia also scored well, with strong scores in each of the indicator components.

Except for Brazil, the Latin American countries (Argentina, Mexico, and Venezuela) received the lowest composite scores of the economies examined. Two factors contributed to their low scores: they were considered riskier or less attractive sites for foreign investment than the other countries, and the experts did not consider these three countries to be entrepreneurial.

Socioeconomic Infrastructure

The socioeconomic infrastructure indicator assesses the underlying physical, financial, and human resources needed to support modern, technology-based nations. It was built from published data on percentages of the population in secondary school and in higher education and survey data evaluating the mobility of capital and the extent to which foreign businesses are encouraged to invest and do business in that country.[16] (See figure 6-15.)

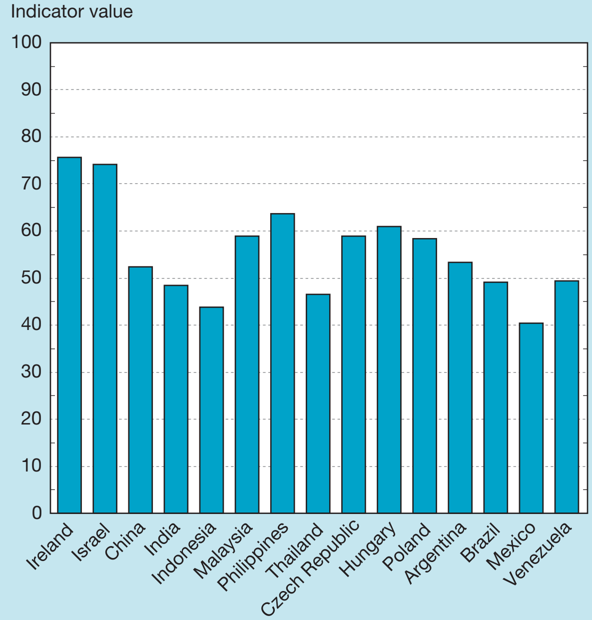
Figure 6-14.
National orientation indicator



NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

Figure 6-15.
Socioeconomic infrastructure indicator



NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

Ireland and Israel again received the highest scores among the emerging and transitioning economies examined. In addition to their strong track records on general and higher education, Ireland's and Israel's scores reflect their high ratings for the mobility of capital and their encouragement of foreign investment. Their scores were similar to those given to Taiwan and South Korea.

Among the remaining nations, the Philippines edged out the three Central European countries, which all posted similar scores. The socioeconomic infrastructure score for the Philippines was bolstered by its strong showing in the published education data and by the experts' higher opinion of its mobility of capital.

Mexico received the lowest composite score of the 15 nations examined. It was held back by low marks on two of the three variables: educational attainment—in particular, university enrollments—and the variable rating of its mobility of capital.

Technological Infrastructure

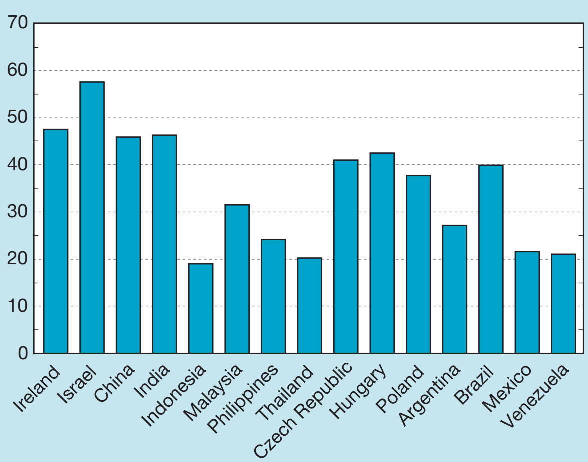
Five variables were used to develop the technological infrastructure indicator, which evaluates the institutions and resources that help nations develop, produce, and market new

[16]The Harbison-Myers Skills Index (which measures the percentage of the population attaining secondary and higher education) was used for these assessments (World Bank 1999).

technology. This indicator was constructed using published data on the number of scientists in R&D; published data on national purchases of electronic data processing (EDP) equipment; and data from a survey that asked experts to rate each nation's ability to train its citizens locally in academic S&E, make effective use of technical knowledge, and link R&D to industry.

Israel received the highest composite score of the group of newly industrialized or transitioning economies examined here. (See figure 6-16.) Israel's high score on this indicator was based on its large number of trained scientists and engineers, the size of its research enterprise, and its contribution to scientific knowledge, especially compared with Ireland and the smaller, less populous nations in Asia and Central Europe. Ireland received the second highest score, followed by India and China. Ireland's score was bolstered by its large purchases of EDP equipment. India's and China's scores were nearly identical, although India's scores showed more balance across indicator components and more overall strength. China's score was influenced greatly by the two components derived from statistical data: its large purchases of EDP equipment and its large number of scientists and engineers engaged in R&D.

Figure 6-16.
Technological infrastructure indicator



NOTE: Raw data were converted into scales of 0–100 for each indicator component.

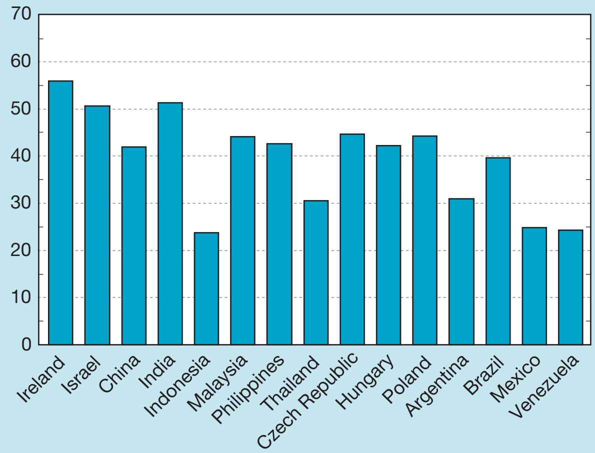
See appendix table 6-8. *Science & Engineering Indicators – 2002*

Productive Capacity

The productive capacity indicator evaluates the strength of a nation's current, in-place manufacturing infrastructure as a baseline for assessing its capacity for future growth in high-technology activities. It factors in expert opinion on the availability of skilled labor, numbers of indigenous high-technology companies, and management capabilities, combined with published data on current electronics production in each country.

Ireland scored highest in productive capacity among the 15 developing and transitioning nations examined, receiving high marks for each indicator component. (See figure 6-17.) Ireland's score also was boosted by its prominence in the computer hardware manufacturing industry. India and Israel were second and third, attaining strong scores on each indicator component.

Figure 6-17.
Productive capacity indicator



NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

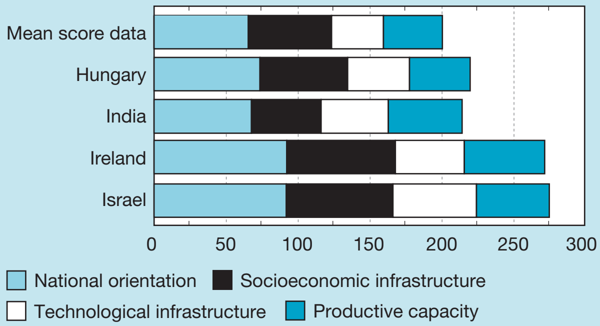
Several developing Asian economies, particularly China and Malaysia, had higher electronics production than did Ireland in 1996, the reference year for the published data. However, they scored lower on indicator components rating their labor pools and management personnel. Mexico's score showed an even greater imbalance than those of China and Malaysia. Although Mexico's production of electronics products—this indicator's published data variable—was greater than Ireland's, scores rating the quality of Mexican labor and management were extremely low. As a result, Mexico received the second lowest score of the 15 countries examined.

Findings From the Four Indicators

Based on the set of four leading indicators discussed, Ireland and Israel appear headed toward prominence as exporters of technology products to the global market. Ireland led the group of 15 developing and transitioning countries examined in three of the four leading indicators and received the second highest score in the fourth, technological infrastructure. On that indicator, Israel ranked first because of its large number of trained scientists and engineers, its highly regarded industrial research enterprise, and its contribution to scientific knowledge. Israel placed second on two of the remaining indicators and third on the other. (See figure 6-18.)

Hungary and India also posted strong scores on at least three of the four indicators. Hungary ranked third on the indicator identifying nations that are taking action to become technologically competitive, fourth on the indicator rating socioeconomic infrastructure, and fifth on the technological infrastructure indicator. India scored nearly as well and some-

Figure 6-18.
Composite scores for four new high-tech exporters



NOTE: Raw data were converted into scales of 0–100 for each indicator component.

See appendix table 6-8. *Science & Engineering Indicators – 2002*

times better than Hungary on the leading indicators, but its scores were not as balanced. Hungary's lowest ranking on any of the four indicators was 8th on the productive capacity indicator, while India's lowest ranking was 11th on the socioeconomic indicator. India's large population helped to elevate its scores on several indicators.

These indicators provide a systematic approach for comparing future technological capability on an even wider set of nations than might be available using other indicators. The results highlight a broadening of the group of nations that may compete in high-technology markets in the future while also reflecting the large differences between several of the emerging and transitioning economies and those considered newly industrialized.

International Trends in Industrial R&D

In high-wage countries such as the United States, industries stay competitive in a global marketplace through innovation (Council on Competitiveness 2001). Innovation leads to better production processes and higher quality products, thereby providing the competitive advantage high-wage countries need when competing against low-wage nations.

R&D activities serve as incubators for the new ideas that can lead to new products, processes, and industries. Although they are not the only source of new innovations, R&D activities conducted in industry-run laboratories and facilities are the source of many important new ideas that have shaped modern technology.[17]

U.S. industries that traditionally conduct large amounts of R&D have met with greater success in foreign markets than those that are less R&D intensive, and they have been more supportive of higher wages for their employees. (See "U.S. Technology in the Marketplace" section for a presentation of recent trends in U.S. competitiveness in foreign and domestic product markets.) Moreover, trends in industrial R&D performance are leading indicators of future technological performance. The following section examines these R&D trends, focusing particularly on growth in industrial R&D activity in the top R&D-performing industries in the United States, Japan, and the EU.[18]

R&D Performance by Industry

The United States, the EU, and Japan represent the three largest economies in the industrialized world and are competitors in the international marketplace. An analysis of R&D data can explain past successes in certain product markets, provide insights into future product development, and highlight shifts in national technology priorities.[19]

United States

R&D performance by the U.S. service-sector industries underwent explosive growth between 1987 and 1991, driven primarily by computer software firms and firms performing R&D on a contract basis. In 1987, service-sector industries performed less than 9 percent of all R&D performed by industry in the United States. During the next several years, R&D performed in the service sector raced ahead of that performed by U.S. manufacturing industries, and by 1989, the service sector performed nearly 19 percent of total U.S. industrial R&D, more than double the share held just two years earlier. By 1991, service-sector R&D had grown to represent nearly one-fourth of all U.S. industrial R&D. Since then, R&D performance in U.S. manufacturing industries increased and began growing faster than in the burgeoning service sector. Manufacturers' share inched back up to 80 percent of total U.S. industry R&D by 1996, the latest year for which internationally comparable data are available. Industries making computer hardware, electronics equipment, and motor vehicles led this resurgence in manufacturing-sector R&D. (See figure 6-19 and appendix table 6-9.)

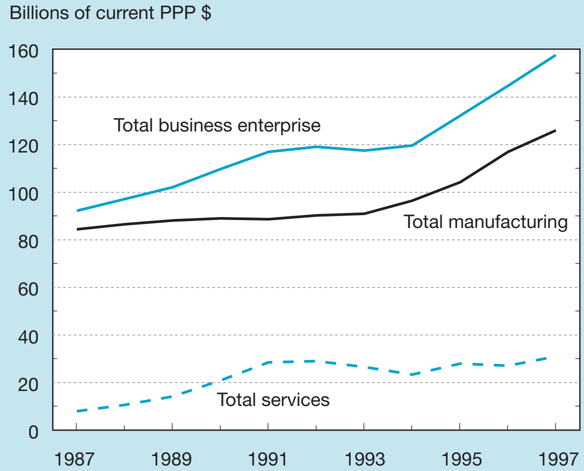
From 1987 to 1992, the U.S. aerospace industry performed the largest amount of R&D, accounting for 14 to 26 percent of total R&D performed by industry. The industry manufacturing electronics equipment (including communications equipment) and the U.S. chemical industry (including pharmaceuticals) followed, each accounting for between 9 and 16 percent of total U.S. R&D. During the mid-1990s, however, the nation's R&D emphasis shifted; the aerospace industry's share declined, and the share for the industry manufacturing communications equipment increased. In 1996 and 1997, the industry manufacturing communications and other electronics equipment was the top R&D performer in the United States.

[17]For a discussion of trends in foreign direct investment in R&D facilities, see chapter 4.

[18]This section uses data from OECD's Analytical Business Enterprise R&D database (OECD 2000) to examine trends in national industrial R&D performance. This database tracks all R&D expenditures (both defense- and nondefense-related) carried out in the industrial sector, regardless of funding source. For an examination of U.S. industrial R&D by funding source, see chapter 4.

[19]Industry-level data are occasionally estimated here to provide a complete time series for the 1987–97 period.

Figure 6-19.
U.S. industrial R&D performance: 1987–97



Top industrial R&D performers and share of total industrial R&D (percents)

1987		1992		1997	
Aerospace	27.1	Services	24.3	Services	19.7
Electronic equipment	15.9	Aerospace	14.8	Electronic equipment	13.0
Chemicals	10.5	Chemicals	12.9	Chemicals	12.1
Computers and office machines	10.1	Computers and office machines	9.6	Computers and office machines	11.6
Motor vehicles	10.1	Electronic equipment	8.9	Aerospace	10.7

PPP = purchasing power parity

See appendix table 6-9. *Science & Engineering Indicators – 2002*

Japan

Unlike the United States, Japan has yet to see a dramatic growth in service-sector R&D. Although R&D in Japan's service-sector industries reached 4.2 percent of the total R&D performed by Japanese industry in 1996 and 4.5 percent in 1997, Japan's industrial R&D performance continues to be dominated by its manufacturing sector. From 1987 to 1995, Japan's manufacturing sector consistently accounted for nearly 98 percent of all R&D performed by Japanese industry. (See figure 6-20 and appendix table 6-10.)[20]

The top industrial R&D performers in Japan during the 1987–97 period reflect that country's long-standing emphases on electronics technology (including consumer electronics and audiovisual equipment), motor vehicles, and electrical machinery. Japan's electronics equipment industry was the leading performer of R&D throughout the period, accounting for nearly 17 percent of all Japanese industrial R&D in 1997. Japan's motor vehicle industry was the second-best R&D performer and has retained that position nearly every year through 1997. Producers of electrical machinery became Japan's second-best R&D-performing industry in 1994 before falling back to the third position, which they have held for several years. In 1997, manufacturers of electrical machinery accounted for nearly 11 percent of all industrial R&D performed in Japan. By comparison, since the early 1970s, U.S. producers of electrical machinery have steadily dropped in rank among the country's top R&D performers.

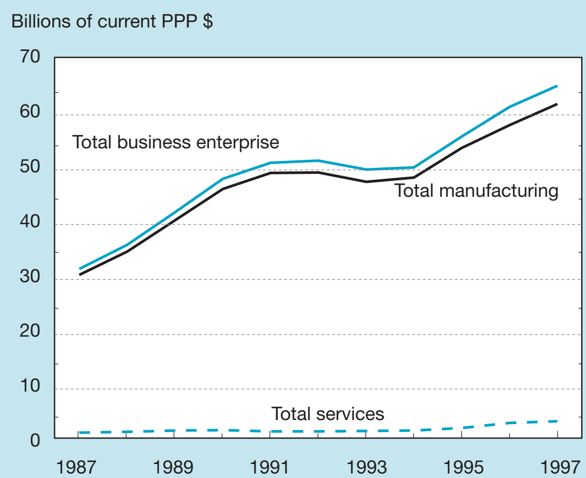
[20]Revised Japanese R&D data for 1997 are reported in the "International Comparisons" section of chapter 4. Those data include a correction not incorporated here because of the inability to carry the correction backward and revise the complete historical series. The revision does not materially alter the observations discussed in this section.

European Union

As in Japan and the United States, manufacturing industries perform the bulk of industrial R&D in the 15-nation EU. The EU's industrial R&D appears to be somewhat less concentrated than that in the United States but more so than that in Japan. Manufacturers of electronics equipment, motor vehicles, and industrial chemicals have consistently been among the top five performers of industrial R&D in the EU. (See figure 6-21 and appendix table 6-11.) In 1997, Germany led the EU in the performance of motor vehicle and industrial chemical R&D, France led in industrial R&D performed by electronics equipment manufacturers, and the United Kingdom led in pharmaceuticals R&D.

R&D within the EU's service sector has doubled since the mid-1980s, accounting for about 11 percent of total industrial R&D by 1997. Large increases in service-sector R&D are apparent in many EU countries, but especially in the United Kingdom (19.6 percent of its industrial R&D in 1997), Italy (15.3 percent), and France (10.0 percent).

Figure 6-20.
Japan industrial R&D performance: 1987–97



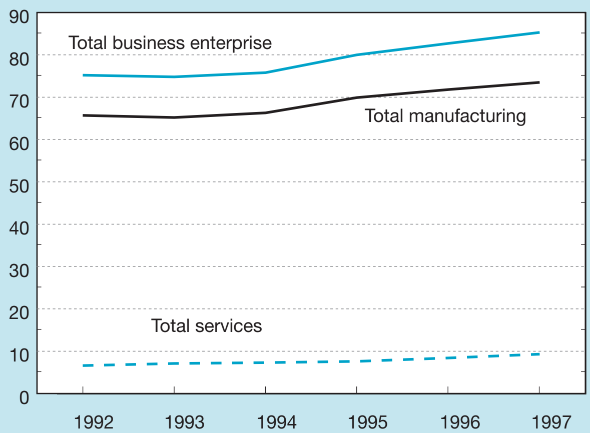
Top industrial R&D performers and share of total industrial R&D (percents)

1987		1992		1997	
Electronic equipment	18.0	Chemicals	16.8	Electronic equipment	16.6
Chemicals	116.9	Electronic equipment	16.7	Chemicals	15.1
Motor vehicles	12.2	Motor vehicles	13.3	Motor vehicles	13.2
Electrical machines	10.3	Office machines	8.6	Electrical machines	10.7
Machinery, N.E.C.	8.2	Machinery, N.E.C.	8.3	Office machines	9.9

PPP = purchasing power parity; N.E.C. = not elsewhere classified

See appendix table 6-10. *Science & Engineering Indicators – 2002*

Figure 6-21.
European Union industrial R&D performance: 1992–97



Top industrial R&D performers and share of total industrial R&D (percents)

1987	1992		1997	
Data not available	Chemicals	19.5	Chemicals	20.7
	Motor vehicles	13.7	Motor vehicles	14.7
	Electronic equipment	10.7	Electronic equipment	12.8
	Aerospace and other transport equipment	10.7	Total services	10.9
	Machinery, N.E.C.	8.8	Aerospace and other transport equipment	8.9

PPP = purchasing power parity; N.E.C. = not elsewhere classified

See appendix table 6-11. *Science & Engineering Indicators – 2002*

Patented Inventions

Inventions have important economic benefits to a nation because they often result in new or improved products, more efficient manufacturing processes, or even new industries. To foster inventiveness, nations assign property rights to inventors in the form of patents, which allow the inventor to exclude others from making, using, or selling the invention. Inventors can obtain patents from government-authorized agencies for inventions judged to be new, useful, and not obvious.

Although the Patent and Trademark Office (PTO) grants several types of patents, this discussion is limited to utility patents only, which are commonly known as patents for inventions. Patenting indicators have several well-known drawbacks, including the following:

- **Incompleteness.** Many inventions are not patented at all, in part because laws in some countries already provide for the protection of industrial trade secrets.
- **Inconsistency across industries and fields.** Industries and fields vary considerably in their propensity to patent inventions; thus, comparing patenting rates among different industries or fields is not advisable (Scherer 1992).
- **Inconsistency in quality.** The importance of patented inventions can vary considerably, although calculating patent citation rates (discussed later in this section and in chapter 5) is one method for mitigating this problem.

Despite these and other limitations, patents provide a unique source of information on inventive activities. Patent data provide useful indicators of technical change and serve as a means of measuring inventive output over time.[21] In addition, information on U.S. patenting by foreign inventors enables measurement of the inventiveness in those foreign countries (Pavitt 1985) and can serve as a leading indicator of new technological competition (Faust 1984).[22]

U.S. Patenting

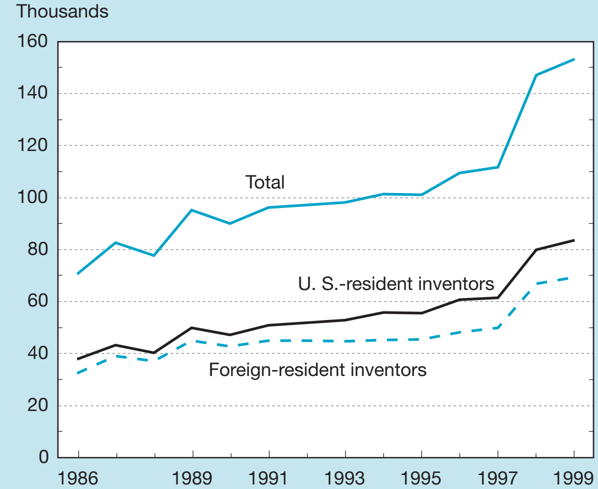
In 1999, more than 153,000 patents were issued in the United States, 4 percent more than that granted a year earlier. This new record number of patents caps off nearly a decade of growth during the 1990s. In 1995, U.S. patents granted fell just short of the previous year's mark, but the upward trend resumed with small increases in U.S. patents granted in 1996 and 1997 before a 32 percent jump in 1998.[23] (See figure 6-22 and appendix table 6-12.)

[21]See Griliches (1990) for a survey of literature related to this point.

[22]It should also be noted that there is concern that patents and other forms of intellectual property may discourage research, its communication, and the difffusion of new technologies. The question arises whether in some respects the extension of intellectual property rights have proceeded too far. To provide answers to guide IPR policy over the next decade and beyond, the Science, Technology and Economic Policy Board (STEP) of theNational Research Council (NRC) has undertaken a project to review the purposes of the IPR legal framework and assess how well those purposes are being served. The Board will identify whether there are current or emerging problems of inadequate or over-protection of IPRs that need attention and will commission research on some these topics.

[23]Although patent applications have been rising, PTO attributes most of the increase in 1998 to greater administrative efficiency and the hiring of additional patent examiners.

Figure 6-22.
U.S. patents granted: 1986–99



See appendix table 6-12. *Science & Engineering Indicators – 2002*

Patents Granted to U.S. Inventors

During the mid-1980s, the share of U.S. patents awarded to U.S. inventors began to decline. Although some observers were concerned that this downward trend indicated a decline in U.S. competitiveness, patenting by U.S. inventors increased by the end of the decade, outpacing patenting by foreign inventors. This upward trend has continued throughout the 1990s, and in 1999, U.S. inventors were awarded nearly 84,000 new patents, an increase of about 4.5 percent over 1998. (See figure 6-22.)

Inventors who work for private companies or the Federal Government commonly assign ownership of their patents to their employers; self-employed inventors typically retain ownership of their patents. Therefore, examining patent data by owner's sector of employment can provide a good indication of the sector in which the inventive work was done. In 1999, corporations owned 80 percent of granted patents.[24] See sidebar, "Top Patenting Corporations." This percentage has gradually increased over the years.[25]

After business entities, individuals are the next largest group of U.S. patent owners. Before 1986, individuals owned, on average, 24 percent of all patents granted to U.S. inventors.[26] Their share has fluctuated downward since then, to a low of 19 percent in 1999. The Federal share of patents averaged 3.3 percent of the total during the period 1963–85, eventually falling to 1.1 percent in 1999, the lowest level ever.[27] U.S. Government-owned patents were encouraged by legislation enacted during the 1980s that called for U.S. agencies to establish new programs and increase incentives to their scientists, engineers, and technicians for the transfer of technology developed in the course of government research.[28]

[24]About 2.2 percent of patents granted to U.S. inventors in 1999 were owned by U.S. universities and colleges. PTO counts these as being owned by corporations. For further discussion of academic patenting, see the chapter 5 section, "Patents Awarded to U.S. Universities."

[25]From 1987 to 1997, corporate-owned patents accounted for between 77 and 79 percent of total U.S.-owned patents. Since 1997, corporations have increased their share each year and, by 1999, represented 82 percent of total U.S.-owned patents.

[26]Before 1986, data are provided as a total for the period 1963–85.

[27]Federal inventors frequently obtain a statutory invention registration (SIR) rather than a patent. The SIR is not ordinarily subject to examination and is less costly to obtain than a patent. Also, the SIR gives the holder the right to use the invention but does not prevent others from selling or using it as well.

[28]The Bayh-Dole University and Small Business Patent Act of 1980 permitted government grantees and contractors to retain title to inventions resulting from federally supported R&D and encouraged the licensing of such inventions to industry. The Stevenson-Wydler Technology Innovation Act of 1980 made the transfer of federally owned or originated technology to state and local governments and to the private sector a national policy and the duty of government laboratories. The act was amended by the Federal Technology Transfer Act of 1986 to provide additional incentives for the transfer and commercialization of federally developed technologies. In April 1987, Executive Order 12591 ordered executive departments and agencies to encourage and facilitate collaborations among Federal laboratories, state and local governments, universities, and the private sector—particularly small business—to aid technology transfer to the marketplace. In 1996, Congress strengthened private-sector rights to intellectual property resulting from these partnerships.

Patents Granted to Foreign Inventors

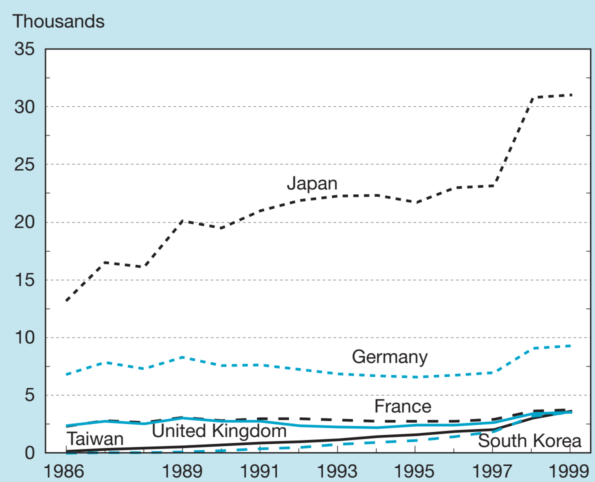
Foreign-origin patents represented 45 percent of all patents granted in the United States in 1999, a share maintained since 1997.[29] During much of the 1980s, foreign-origin patents increased at a faster rate than U.S.-origin patents, reaching a peak of 48 percent of all U.S. patents in 1989. From the following year until 1996, U.S. inventor patenting increased at a faster pace than that of foreign inventors, dropping the foreign share to 44 percent. In 1999, two countries (Japan and Germany) accounted for just more than 58 percent of U.S. patents granted to foreign inventors. The top four countries (Japan, Germany, France, and the United Kingdom) accounted for about 70 percent. (See figure 6-23 and appendix table 6-12.)

Although patenting by inventors from the leading industrialized countries has leveled off or even declined, some Asian economies, particularly Taiwan and South Korea, have stepped up their patenting activity in the United States and are proving to be strong inventors of new technologies.[30] Between 1963 (the year data first became available) and 1985, Taiwan was awarded just 742 U.S. patents. During the 14-year period since then, Taiwan was awarded more than 19,000 U.S. patents. U.S. patenting activity by inventors from South Korea shows a similar growth pattern. Before 1986, South Korea was awarded just 213 U.S. patents; since then, it has been awarded more than 14,000 new patents. In 1998, Taiwan and South Korea surpassed Canada to become the fifth and sixth most active foreigner inventors in the United States. Sweden and the Netherlands also had large increases in U.S. patenting in 1998.

[29]Corporations account for about 80 percent of all foreign-owned U.S. patents.

[30]Some of the decline in U.S. patenting by inventors from the leading industrialized nations may be attributed to the move toward European unification, which has encouraged wider patenting within Europe.

Figure 6-23.
U.S. patents granted to foreign inventors, by residence of inventor: 1986–99



NOTE: Selected economies are the top six recipients of U.S. patents during 1999.

See appendix table 6-12. *Science & Engineering Indicators – 2002*

Top Patenting Corporations

A review of the top patenting corporations in the United States during the past 25 years illustrates the technological transformation achieved by Japan over a relatively short period. In 1973, no Japanese companies ranked among the top 10 patenting corporations in the United States. In 1983, however, 3 of the top 10 were Japanese companies. By 1993, Japanese companies outnumbered U.S. companies, and in 1996, 7 of the top 10 were Japanese companies. The most recent data (1999) show a South Korean company (Samsung Electronics Company), 3 U.S. companies, and 6 Japanese companies among the top 10. (See text table 6-2.) Samsung ranked 4th among patenting corporations in the United States in 1999 after ranking 17th just two years earlier. South Korea's U.S. patenting now emphasizes computer, television and communications, and power generation technologies. Despite their economic problems, South Korea and Japan have achieved continued success in patenting inventions in the United States, illustrating their growing ability to innovate in important technologies.

IBM was awarded more patents than any other U.S. organization in 1999, the seventh consecutive year that the company has earned this distinction. Lucent Technologies joined the top 10 for the first time with 1,153 patents, nearly a quarter more than it received just a year earlier. The only other U.S. company making the top 10, Motorola, dropped from fourth to eighth place with 1,192 patents in 1999, more than 200 fewer than it received in 1998.

Text table 6-2.
Top patenting corporations

Company	Patents
1999	
International Business Machines Corp.	2,756
NEC Corporation	1,842
Canon Kabushiki Kaisha	1,795
Samsung Electronics Co., Ltd.	1,545
Sony Corporation	1,409
Toshiba Corporation	1,200
Fujitsu Limited	1,193
Motorola, Inc.	1,192
Lucent Technologies	1,153
Mitsubishi Denki Kabushiki Kaisha	1,054
1977–96	
General Electric Corp.	16,206
International Business Machines Corp.	15,205
Hitachi Ltd.	14,500
Canon Kabushiki Kaisha	13,797
Toshiba Corporation	13,413
Mitsubishi Denki Kabushiki Kaisha	10,192
U.S. Philips Corporation	9,943
Eastman Kodak Company	9,729
AT&T Corporation	9,380
Motorola, Inc.	9,143

SOURCE: U.S. Patent and Trademark Office, Information Products Division, Technology, Assessment, and Forecast Branch, special tabulations (November 2000).

Science & Engineering Indicators – 2002

Trends in Applications for U.S. Patents

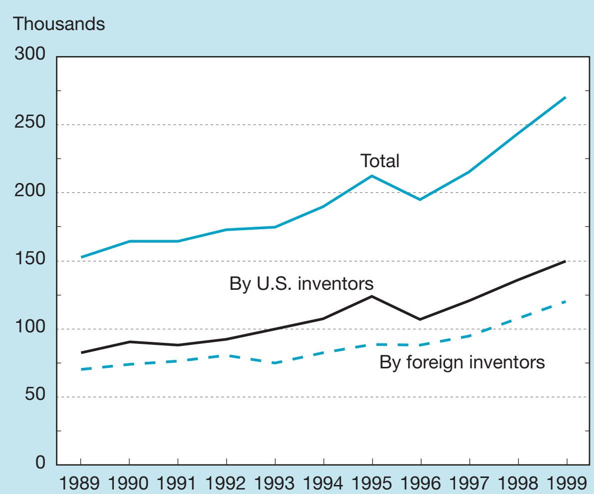
The review process leading up to the official grant of a new patent may take as long as 2 years. Consequently, the examination of year-to-year trends in patents granted will not always reveal the most recent changes in patenting activity. The number of patent applications filed with the PTO provides an earlier, albeit less certain, indication of changes to patterns of inventiveness. Yet, current trends in new patent applications help to revise observations made from the more informative data, presented earlier, on trends in U.S. patents granted.

Patent Applications From U.S. and Foreign Inventors

Applications for U.S. patents reached 270,000 in 1999, an increase of about 11 percent over 1998. These latest data extend what has been nearly a decade of annual increases. During the past 11 years, the only significant decline in patent applications occurred in 1996. (See figure 6-24 and appendix table 6-13.)

U.S. resident patents represented 56 percent of all patents applied for in the United States in 1999, a share maintained since

Figure 6-24.
U.S. patent applications: 1989–99



See appendix table 6-13. *Science & Engineering Indicators – 2002*

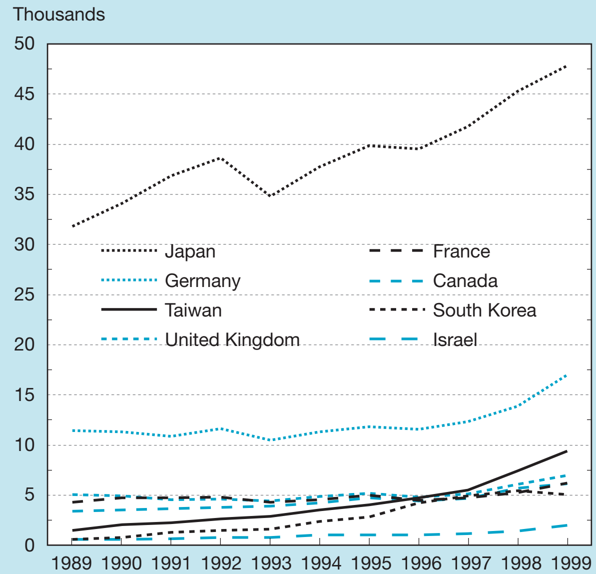
1997. Because patents granted to foreign inventors have generally accounted for about 45–47 percent of total U.S. patents granted, it appears that the success rate for foreign-origin patents is lower than that for those applied for by U.S. inventors.

In 1999, two countries, Japan and Germany, accounted for nearly 44 percent of U.S. patent applications made by foreign inventors. Although patent filings by inventors from the leading industrialized countries have leveled off and have even begun to decline, other countries, particularly Asian countries with the exception of Japan, have stepped up their patenting activity in the United States. This is especially true for Taiwan and South Korea, and the data on recent patent applications indicate that this trend continues.

Since 1997, residents of Taiwan and South Korea have distinguished themselves in the number of applications for U.S. patents. In 1997, the number of patents applied for by residents of Taiwan and South Korea ranked them among the top five for the first time, replacing residents from France and Canada. Residents of Taiwan had moved up further in 1998 to become the third leading source for new U.S. patent applications. In 1999, residents of Taiwan applied for more than 9,000 new patents, an increase of 27 percent from a year earlier and more than 2,400 than that made by residents of the United Kingdom, ranked fourth. If recent patents granted to residents of Taiwan are indicative of the technologies awaiting review, then many of these applications will be for new computer and electronic inventions. Compared with the rising trend in Taiwan's U.S. patent applications, recent filings by inventors from South Korea have not continued at the same pace.

Although less dramatic than that demonstrated by inventors from Taiwan and South Korea, patent applications by inventors from Germany, France, and Israel also increased in 1999. Inventors residing in Israel were particularly active, increasing their applications for U.S. patents by about 39 percent from a year earlier. (See figure 6-25.)

Figure 6-25.
U.S. patent applications filed by selected foreign inventors, by residence of inventor: 1989–99



See appendix table 6-13. *Science & Engineering Indicators – 2002*

Technical Fields Favored by U.S. and Foreign Inventors

A country's distribution of patents by technical area is a reliable indicator of both its technological strengths and its focus on product development. This section compares and discusses the various key technical fields favored by U.S. inventors and the top five foreign inventors patenting in the United States.[31] Patent activity in the United States by inventors from foreign countries can be used to identify a country's technological strengths as well as U.S. product markets likely to see increased competition.

Fields Favored by U.S. and Leading Foreign Inventors

Although U.S. patent activity encompasses a wide spectrum of technology and new product areas, U.S. corporations' patenting emphasizes several technology areas expected to play an important role in the nation's future economic growth (U.S. Office of Science and Technology Policy 1997). In 1999, corporate patent activity reflected U.S. technological strengths in medical and surgical devices, electronics, telecommunications, advanced materials, and biotechnology. (See text table 6-3.)

The 1999 patent data show not only Japan's continued emphasis on photocopying, photography, and consumer electronics technology but also its broader range of U.S. patents in information technology. From improved information storage technology for computers to visual display systems, Japanese inventions are earning U.S. patents in areas that aid in the processing, storage, and transmission of information.

German inventors continue to develop new products and processes in technology areas associated with heavy manufacturing, a field in which it has traditionally maintained a strong presence. The 1999 U.S. patent activity index shows that Germany emphasizes inventions for motor vehicles, printing, new chemistry and advanced materials, and material-handling equipment.

In addition to inventions for traditional manufacturing applications, British patent activity is also high in biotechnology and chemistry. Like the British, the French are quite active in patent classes associated with manufacturing applications and biotechnology. They share the emphasis of U.S. inventors in aeronautics and communications technologies.

[31]Information in this section is based on PTO's classification system, which divides patents into approximately 370 active classes. With this system, patent activity for U.S. and foreign inventors in recent years can be compared by using an activity index. For any year, the activity index is the proportion of patents in a particular class granted to inventors in a specific country divided by the proportion of all patents granted to inventors in that country. Because U.S. patenting data reflect a much larger share of patenting by individuals without corporate or government affiliation than do data on foreign patenting, only patents granted to corporations are used to construct the U.S. patenting activity indices.

Text table 6-3.
Top 15 most emphasized U.S. patent classes for corporations from United States, Japan, and Germany: 1999

	United States	Japan	Germany
1.	Surgical instruments	Information storage and retrieval	Plant protecting and regulating compositions
2.	Biology of multicellular organisms	Television signal processing	Clutches and power-stop control
3.	Surgery: light, thermal, and electrical applications	Photocopying	Printing
4.	Wells	Electrophotography	Brake systems
5.	Data processing	Photography	Metal deforming
6.	Digital processing systems	Liquid crystal cells	Bodies and tops for land vehicles
7.	Information processing system organization	Crystal growth processes	Winding, tensioning, or guiding devices
8.	I/O digital processing systems	Interrelated power delivery controls	Internal combustion engines
9.	Surgery (medicators and receptors)	Facsimile	Bleaching and dyeing of textiles
10.	Business practice, dataprocessing	Incremental printing of symbolic information	X-ray or gamma-ray systems
11.	Computer memory	Music	Machine element or mechanism
12.	Computer processing architectures	Brake systems	Electrical transmission systems
13.	Aeronautics	Typewriting machines	Land vehicles
14.	Electronic digital logic circuitry	Radiation imagery chemistry	Power plants
15.	Surgery	Internal combustion engines	Organic compounds

I/O = Input/output

NOTES: Ranking is based on patenting activity of nongovernment U.S. or foreign organizations, which are predominately corporations. Patenting by individuals and governments is excluded.

SOURCE: U.S. Patent and Trademark Office, Office of Information Services, TAF Program, 2001. *Science & Engineering Indicators – 2002*

As recently as 1980, Taiwan's U.S. patent activity was concentrated in the area of toys and other amusement devices. By the 1990s, Taiwan was active in communications technology, semiconductor manufacturing processes, and internal combustion engines. The data from 1999 show that Taiwan's inventors have continued to broaden their technology portfolio, emphasizing testing and measuring devices, audio systems, advanced materials, optics, and aeronautics.

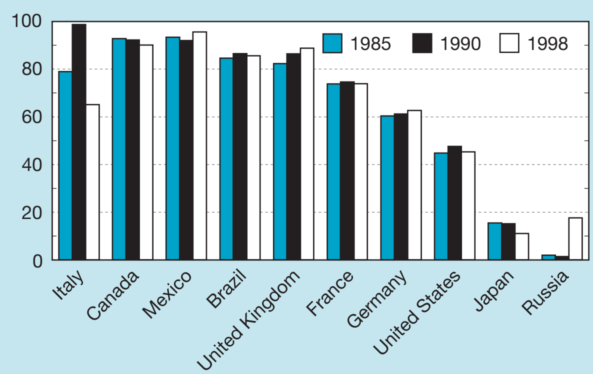
U.S. patenting by South Korean inventors has also reflected that country's rapid technological development. The 1999 data show that South Korean inventors are patenting heavily in television technologies and a broad array of computer technologies that include devices for dynamic and static information storage, data generation and conversion, error detection, and display systems. (See text table 6-4.)

Both South Korea and Taiwan are major suppliers of computers and peripherals to the United States, and recent patenting data show that their scientists and engineers are developing these new technologies and improving existing ones. These new inventions are likely to enhance their competitiveness in the United States and in the global market.

Patenting Outside the United States

In most countries, foreign inventors account for a much larger share of total patent activity than in the United States. When foreign patent activity in the United States is compared with that in 11 other countries in 1985, 1990, and 1998, only Russia and Japan consistently had smaller shares of foreign patent activity. (See figure 6-26.)

Figure 6-26.
Share of total patents awarded to nonresident inventors in selected countries



See appendix tables 6-12 and 6-14.

Science & Engineering Indicators – 2002

Although much attention is given to the level of foreign patenting in the United States, this tends to overshadow the success of U.S. inventors in patenting their inventions around the world. In 1998, U.S. inventors led all other foreign inventors not only in countries neighboring the United States but also in markets such as Germany, Japan, France, Italy, Brazil, Russia, Malaysia, and Thailand. (See figure 6-27 and appendix table 6-14.) Japanese inventors edge out Americans in China and dominate foreign patenting in South Korea. German inventors are also quite active in many of the other countries examined.

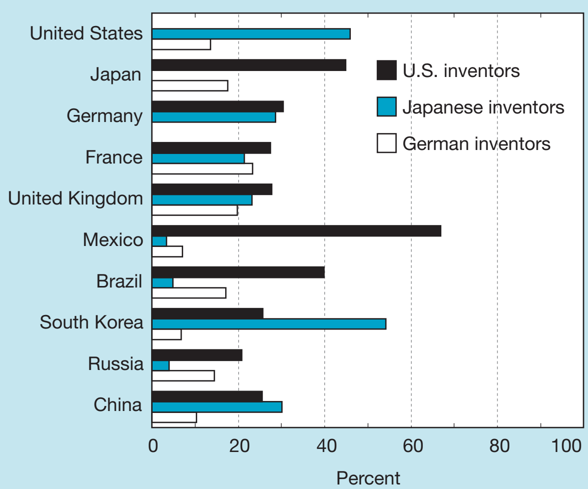
Text table 6-4.
Top 15 most emphasized U.S. patent classes for corporations from South Korea and Taiwan: 1999

	South Korea	Taiwan
1.	Transmission systems	Semiconductor device manufacturing process
2.	Liquid crystal cells, elements and systems	Electrical connectors
3.	Refrigeration	Solid state devices
4.	Static information storage and retrieval	Music
5.	Power delivery controls	Circuit makers and breakers
6.	Television signal processing for recording	Substrate etching processes
7.	Television	Receptacles
8.	Semiconductor device manufacturing process	Electrical systems and devices
9.	Dynamic magnetic information storage or retrieval	Chairs and seats
10.	Electric heating	Computers
11.	Miscellaneous active electrical nonlinear devices	Illumination
12.	Electric lamp and discharge devices	Electrical power conversion systems
13.	Electric lamp and discharge systems	Static information storage and retrieval
14.	Active solid-state devices	Supports
15.	Electric power conversion systems	Coded data generation

NOTE: Ranking is based on patenting activity of nongovernmental organizations, which are primarily corporations. Patenting by individuals and governments is excluded.

SOURCE: U.S. Patent and Trademark Office, Office of Information Services, TAF Program, 2001. *Science & Engineering Indicators – 2002*

Figure 6-27.
Patents granted to nonresident inventors in selected countries: 1998



See appendix table 6-14. *Science & Engineering Indicators – 2002*

International Patenting Trends in Two New Technology Areas[32]

This section explores the relative strength of America's inventiveness by examining international patenting patterns in two new technology areas: human DNA sequences and business methods. The analysis is built around the concept of a "patent family," i.e., all the patent documents published in a country associated with a single invention. See sidebar, "International Patent Families As a Basis for Comparison."

Three indicators are used here to compare national positions in each technology area:

- ♦ **Trends in international inventive activity.** This indicator is a preliminary measure of the extent and growth of inventive activity considered important enough to be patented outside the country of origin. These data are tabulated by priority year.
- ♦ **Number of organizations assigned patents.** The number of organizations in a country that are active in a technology may indicate a country's ability to innovate and its potential for innovative activity. Research by Michael Porter (1990) suggests that the growth of clusters of innovative organizations is associated with national competitiveness. The Council on Competitiveness (2001) also associates clusters of innovation with higher rates of innovation, productivity growth, and new business formation.
- ♦ **Highly cited inventions.** Interpatent citations are an accepted method of gauging the technological value or significance of different patents. These citations, provided by the patent examiner, indicate the "prior art" (the technology in related fields of invention) that is taken into account in judging the novelty of the present invention.[33] The number of citations a patent receives from later patents can serve as an indicator of its technical importance or value.

[32]Information presented in this section was developed by Mogee Research & Analysis Associates under contract to the National Science Foundation. (See Mogee April 2001 and Mogee June 2001).

[33]The citations counted are those placed on European Patent Office (EPO) patents by EPO examiners. EPO citations are believed to be a less biased and broader source of citations than those of PTO. See Claus and Higham (1982).

International Patent Families As a Basis for Comparison

A *patent family* consists of all the patent documents associated with a single invention that are published in one country. Although counting patent families gives a rough estimate of a nation's technological activity, international comparisons based solely on numbers of patent families can be misleading because differing national patent laws and customs can result in higher levels of patenting in some countries than in others. In addition, a patent generally offers protection only in the country in which it is issued; to protect an invention in multiple countries, multiple patent applications must be filed. Because it is extremely costly to pursue patent protection in multiple countries, organizations are assumed to seek patent protection abroad only for those inventions they believe will have significant commercial value. Patent families for which protection has been sought in more than one country are counted separately here and called *international patent families.* Counting international patent families makes international comparisons more accurate and theoretically provides a more precise measure of technological activity intended for international use.

Patents in a family are linked together through *priority* details. Priority is established by the application date assigned in the first country in which the invention was filed for protection. Under the Paris Convention, if the invention is filed in another convention country within one year of the original filing, the patent in the second country can claim the original priority. The country in which the priority application was filed is assumed to be the country in which the invention was developed. Similarly, the priority year is the year the priority application was filed.

This study was undertaken to provide data on the growth of patenting in these two technology areas, identify which groups are doing the patenting, and compare the position of the United States with that of other nations. The study examined patenting in more than 40 countries, including the United States, Japan, European countries, and other major industrialized and industrializing countries.

International Patenting of Human DNA Sequences

Whether human DNA sequences should be patentable has been strongly debated for many years.[34] Some have argued that patents on human DNA sequences are necessary to make diagnostic and therapeutic products commercially available. Others argue that giving companies monopoly rights over specific DNA sequences will hinder scientific progress.

Despite the ongoing controversies, patent offices worldwide have issued thousands of patents on human DNA sequences. As researchers move from mapping sequences to decoding their functions and manipulating them for diagnostic and therapeutic purposes, their work will transform the way many diseases are treated. The companies and countries that own key patents will benefit most from these developments. See sidebar, "Patenting of Human DNA Sequences: A Recent Invention."

Number of International Patent Families. Strong, steady growth in the number of international patent families in human DNA sequencing mirrors the growth in total patent families.[35] (See figure 6-28 and appendix table 6-15.) The United States accounts for a slightly higher share of international patent families (72 percent) than total families (69 percent). Overall, 75 percent of all U.S. patent families in this technology are international patent families. In contrast to the United States, only about 51 percent of Japan's total patent families are international patent families. As with total families, Great Britain ranks third in international patent families. China, which has 145 total patent families in this technology, has only 17 international patent families, possibly indicating that their patents are of lesser commercial value.

The United States appears to be the market of greatest interest to organizations patenting human DNA sequences, with protection being sought for more than 73 percent of all patented inventions in this field. (See text table 6-5.) Although most countries automatically publish patent applications 18 months after the priority application is filed, during the time period covered by this study, PTO published only granted patents, not applications. For this reason, there are probably additional patent families in this study for which protection

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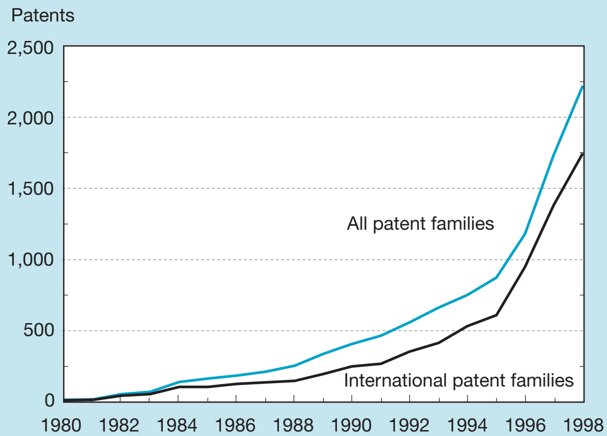
[34]Data on patents covering human DNA sequences were drawn from GENESEQ and the Derwent World Patents Index (DWPI), two on-line databases published by Derwent Publications. GENESEQ is the world's most comprehensive database devoted exclusively to patented sequence information, and each patent record in GENESEQ is reviewed and coded by molecular biologists at Derwent. Patents are included that claim DNA sequences or that refer to DNA sequences in their claims. A search was conducted in GENESEQ for all gene sequence patents that had been coded by the experts as relating to humans. GENESEQ records go back to 1981.

Each GENESEQ record corresponds to a patented sequence, rather than a patent, and gives only the basic patent number covering each sequence. Therefore, the basic patent numbers were mapped from the GENESEQ search into the DWPI, which covers patenting from more than 40 different countries and patent-granting authorities, to retrieve more complete patent family information. Each DWPI record constitutes a patent family, which avoids the problem of double counting inventions patented in more than one country. Using this procedure, 10,759 Derwent records were obtained, with 1980 as the earliest priority year.

[35]Because of the time lag between patent application and publication, data for 1999 should be considered incomplete.

Figure 6-28.
Human DNA sequence patent families worldwide: 1980–98



See appendix table 6-15. *Science & Engineering Indicators – 2002*

has been sought in the United States but for which no patent has yet been granted. Therefore, it is likely that the United States is undercounted in this table.

Europe and Japan also appear to be significant markets for organizations patenting human DNA sequences. Approximately half the patent families in this technology have protection in Europe, and protection has been sought in Japan for about 36 percent. Australia ranks fourth, with nearly 11 percent having sought protection in that country.[36]

Number of Organizations Assigned Patents. The number of technologically active organizations in a country may indicate that nation's current and potential level of innovation.

[36]If a Patent Cooperation Treaty (PCT) application lists Australia as a "designated state," Australia automatically publishes an Australian document, which the PCT applicant may not complete. To avoid spurious counts for protection in Australia, Australia was counted as a patent country only if the patent publication was a "B" (i.e., second stage) document or if no PCT application was on the record.

Text table 6-5.
Total number of patent families seeking patent protection in each country or region during 1980-99: Human DNA Sequences

Country/region	Patent families
Total families	10,759
United States	7,906
Europe	5,393
Japan	3,926
Australia	1,142
Canada	817
South Africa	637
Latin America	578
China	479
South Korea	460

SOURCE: "International Analysis of Human DNA Sequence Patenting," submitted to the National Science Foundation by Mogee Research and Analysis Associates (Reston, VA, April 10, 2001).

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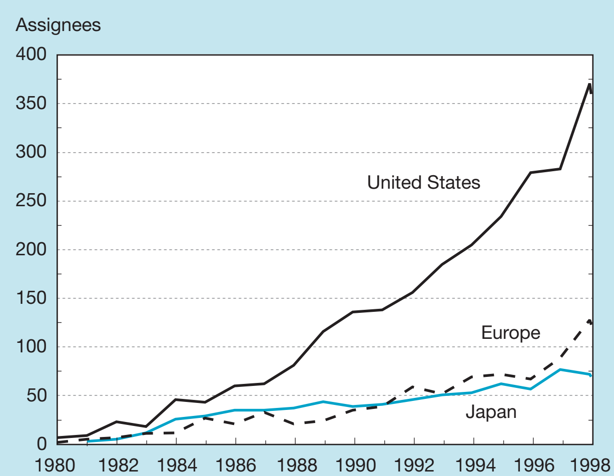
The United States has had the most organizations actively filing patent applications for human DNA sequences every year since 1980. (See figure 6-29 and appendix table 6-16.) Since 1995, the United States has consistently had 3 to 7 times the number of patenting organizations as Japan, which has ranked second every year since 1983. Great Britain has ranked third every year during that time period, except 1988. Although still quite low, patenting organizations in several countries, including Australia, China, Israel, Sweden, and South Korea, have increased significantly in number during the past few years.

Although corporations dominate human DNA patenting overall, the types of organizations actively patenting human DNA sequences vary among priority countries.[37] (See text table 6-6.) The majority of patenting organizations in Germany, France, Israel, and Japan are corporations; few universities, nonprofit organizations, or government agencies file priority applications in these countries. The United States and Great Britain have the largest number of universities seeking patents for human DNA sequences, although far more corporations than universities are active in these countries. Unlike the other major patenting countries, Australia, Canada, and China tend to have as many or more universities than corporations seeking patents for human DNA sequences.

Highly Cited Patents. The size of a country's share of the top-cited patent families is attributable partly to the technological significance of its patents and partly to the total number of patents it has. A country's share of the most highly cited patent families can be expressed as a ratio of its representation among highly cited patent families to its representation among

[37]As in appendix table 6-16, text table 6-6 shows the number of unique organizations filing patent applications, not the number of applications they have filed. In this table, individuals are included if no other type of organization was assigned the patent. If a company was assigned a patent and it was coassigned to the individual, the individual was assumed to be an employee of the company. If two organizations, such as a company and a university, were coassigned a patent, both were counted.

Figure 6-29.
Active assignees for DNA patents, United States, Japan, and Europe: 1980–98



See appendix table 6-16. *Science & Engineering Indicators – 2002*

Patenting of Human DNA Sequences: A Recent Invention

The patenting of genes and gene sequences has a relatively short history. The surge in patenting since 1990 has been fueled by the Human Genome Project, which has generated huge amounts of information on genes and gene fragments. In 2000, the Patent and Trademark Office (PTO) issued about 2,000 patents on full-length genes for all species. Reportedly, more than 3 million expressed sequence tabs (ESTs) and thousands of other partial and whole genes are included in pending patent applications in the United States. Some observers are concerned that patents on gene fragments, such as ESTs and single-nucleotide polymorphisms, might make the fragments unavailable to researchers or force researchers to negotiate a formidable web of licenses to work with the fragments. Such obstacles may hamper not only basic research but also research into cures for diseases.

The patentability of genes and gene sequences in the United States is based on the 1980 Supreme Court decision *Diamond* v. *Chakrabarty*, which ruled that genetically engineered living organisms could be patented. This decision was followed by internal actions by PTO in the mid-1980s that extended patentability to plants and nonhuman animals. In 1995, the U.S. Court of Appeals for the Federal Circuit affirmed that partially published sequences were patentable in a case *(In re Deuel)* used by PTO to support its policy of awarding patents for genes and gene sequences. PTO issued the first patent for an EST in October 1998 to InCyte Pharmaceuticals Inc.

Much of the research community was critical of patenting gene segments, especially when specific functions and applications were not known. Important research groups, such as the Human Genome Organization and the National Institutes of Health, argued that DNA patents should be granted only when specific applications are described or detailed information about the gene is supplied. In response to this criticism, PTO revised its examination guidelines on January 5, 2001. Under the new guidelines, an invention must be supported by "at least one specific, substantial, and credible or a well-established utility." This requirement may reduce the number of patent applications for genes or gene sequences.

In Europe, the European Union Council approved a directive on the legal protection of biotechnological invention in 1998 to harmonize and clarify the laws of the European nations and the European Patent Office. The directive states that a DNA sequence alone, without an indication of its function, is not patentable; the gene sequence must have an industrial application that is disclosed in the patent specification. If a gene sequence is used to produce a protein, the applicant must specify both the protein produced and the protein's function.

Until 1979, the Japanese Patent Office (JPO) took the position that microorganisms were not patentable because there were no industrial applications for them. In 1979, JPO reversed its position and issued a set of Working Standards on microorganisms. According to the Working Standards, DNA molecules were patentable, but patents were granted only to applicants who finished decoding procedures and could describe the DNA functions. In 1999, JPO announced that it would allow patents on DNA fragments if those fragments were shown to be effective for specific purposes, such as diagnosing or curing certain diseases.

Thus, three major patent offices have arrived at a consensus substantially in accord with that of the research community: that DNA fragments for which only sequence or alignment have been identified are not patentable. A DNA fragment is patentable only if it has a specific, useful application and if it meets the additional criteria that all patents must meet; that is, novelty, nonobviousness, and enablement.

the total families in a particular technology. (See text table 6-7.) A value of 1.0 indicates that a country's share of the highly cited families is identical to its share of total families; a value greater than 1.0 in the ratio column indicates that a country is overrepresented, while a score of less than 1.0 indicates that a country's patent families are undercited.

Although during the past 20 years the United States has had the largest number of highly cited patents in this technology by far, its total number of highly cited patents has been about what would be expected based on its overall level of patenting. Japan has been somewhat underrepresented among the most highly cited patents in each of the four time periods. One possible explanation for this is that about half of Japan's patent families are protected only in Japan, and examiners at the European Patent Office (EPO) may be less likely to cite such patents. Great Britain was significantly overrepresented among the most highly cited patents in the 1985–89 time period, but during the last two time periods, Great Britain's share of the most highly cited patents has been about what would be expected based on its level of activity. Germany had about twice as many highly cited patents as would be expected in the 1985–89 and 1990–94 time periods but fewer than would be expected during the last time period. Because these citations come from EPO, one might expect that EPO patents would be overrepresented; however, this occurred in only the 1990–94 time period. EPO priority patents were

Text table 6-6.
Active assignees, by priority country and period: Human DNA Sequences patents

Priority country	1980–84	1985–89	1990–94	1995–99
Australia				
Corporations	1	5	4	16
Universities	3	4	6	16
Not for profits	0	2	2	6
Government agencies	0	0	1	3
Individuals	0	0	0	1
Canada				
Corporations	1	3	2	8
Universities	1	2	4	13
Not for profits	0	0	0	0
Government agencies	0	0	1	0
Individuals	0	0	3	7
China				
Corporations	0	0	1	4
Universities	0	0	0	6
Not for profits	0	0	0	2
Government agencies	0	0	0	5
Individuals	0	0	0	5
Germany				
Corporations	4	9	14	33
Universities	0	0	3	9
Not for profits	0	0	4	8
Government agencies	0	0	1	5
Individuals	0	0	3	38
European Patent Office				
Corporations	1	12	12	40
Universities	1	2	1	16
Not for profits	1	1	2	11
Government agencies	0	1	3	3
Individuals	0	3	3	9
France				
Corporations	1	6	16	20
Universities	0	3	2	3
Not for profits	0	2	3	7
Government agencies	0	3	4	5
Individuals	0	0	10	0
Great Britain				
Corporations	10	29	45	63
Universities	2	0	18	27
Not for profits	3	1	7	9
Government agencies	0	1	8	4
Individuals	0	1	2	4
Israel				
Corporations	1	2	5	12
Universities	0	0	1	2
Not for profits	0	1	0	0
Government agencies	1	0	0	1
Individuals	0	0	0	0
Japan				
Corporations	27	65	93	117
Universities	3	6	2	0
Not for profits	2	4	6	7
Government agencies	1	5	6	9
Individuals	1	11	19	15
United States				
Corporations	52	116	241	412
Universities	13	53	108	163
Not for profits	7	23	48	59
Government agencies	1	7	13	20
Individuals	4	16	31	82

NOTE: Priority country is established by the location of the original patent application.

SOURCE: "International Analysis of Human DNA Sequence Patenting," submitted to the National Science Foundation by Mogee Research and Analysis Associates (Reston, VA, April 10, 2001).

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Text table 6-7.
Priority countries ranked by share of top-cited patents: Human DNA Sequences

Priority country	Share of top cited (percent)	Share of total families (percent)	Ratio top cited to total families
1980–84			
United States	80.0	56.8	1.4
Great Britain	10.0	10.1	1.0
Japan	10.0	23.6	0.4
1985–89			
United States	62.3	61.6	1.0
Japan	16.4	23.2	0.7
Great Britain	8.2	4.8	1.7
Germany	3.3	1.8	1.8
Denmark	2.5	0.9	2.8
France	2.5	2.1	1.2
European Patent Office	1.6	2.1	0.8
Israel	1.6	0.8	2.0
Netherlands	0.8	0.5	1.6
Sweden	0.8	0.3	2.7
1990–94			
United States	69.8	71.9	1.0
Japan	10.8	14.1	0.8
Great Britain	4.7	4.2	1.1
Germany	4.3	2.2	2.0
European Patent Office	2.6	1.4	1.9
France	2.6	1.9	1.4
Australia	1.3	0.7	1.9
Denmark	1.3	0.7	1.9
Israel	1.3	2.0	0.7
Canada	0.9	2.6	0.3
Italy	0.4	1.0	0.4
1995–99			
United States	76.8	70.3	1.1
Japan	9.8	11.0	0.9
Great Britain	4.8	5.0	1.0
European Patent Office	2.7	2.8	1.0
Germany	2.1	3.2	0.7
Australia	1.8	1.2	1.5
France	1.2	1.3	0.9
Canada	0.3	0.8	0.4
Denmark	0.3	0.3	1.0
Israel	0.3	0.4	0.8

NOTE: Priority country is established by the location of the original patent application.

SOURCE: “International Analysis of Human DNA Sequence Patenting,” submitted to the National Science Foundation by Mogee Research and Analysis Associates (Reston, VA, April 10, 2001).

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underrepresented among the most highly cited in the 1985–89 time period and are about what would be expected in the 1995–99 time period. Care should be taken not to read too much into the ratios for countries with low levels of activity because one or two highly cited patents from these countries may make them appear to be overrepresented among the highly cited families.

International Patenting of Internet-Related Business Methods

During the 1990s, the Internet spurred the development of new methods to conduct business, and growing numbers of companies sought patent protection for these new business models.[38] The patenting of Internet business methods has been nearly as controversial as the patenting of human DNA sequences. See sidebar, "Patenting of Internet Business Methods in the United States, Japan, and Europe."

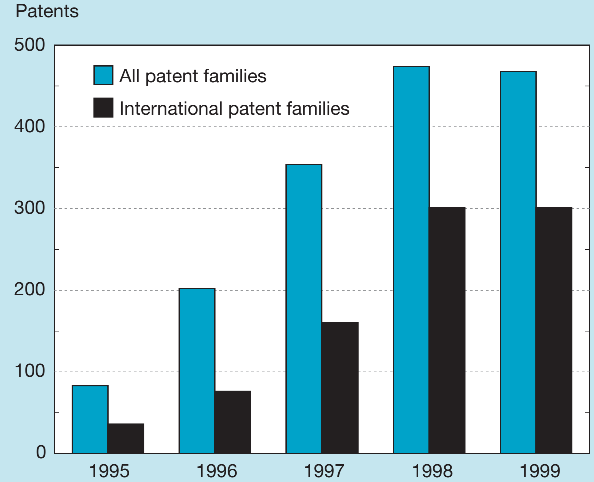
This section examines the growth of patenting of Internet business methods, which nations are doing the patenting, and the position of the United States in global patenting. The data include recent patenting trends in more than 40 countries, although the section focuses primarily on the major actors in this field, the United States, Japan, and Europe.

Number of International Patent Families. Strong, steady growth in the number of international patent families in this technology mirrors the growth in total patent families.[39] (See figure 6-30 and appendix table 6-17.) The United States accounts for a significantly higher share of international patent families (72 percent) than total families (50 percent). Overall, 78 percent of all U.S. patent families in this technology are international patent families. Japan ranks second in international families (7 percent). However, in contrast with the United States, only about 15 percent of all Japanese patent families are international patent families. Great Britain ranks third in international patent families (3.5 percent), followed by Germany (2.2 percent).

The United States appears to be the market of greatest interest to organizations patenting Internet business methods, which sought protection there for more than 52 percent of all patented inventions in this field.[40] (See text table 6-8.) Although most countries automatically publish patent applications 18 months after the priority application is filed, during the time period covered by this study, PTO published only granted patents, not applications; therefore, the United States is probably underrepresented in text table 6-8.

Japan and Europe also appear to be markets of significant interest to organizations patenting Internet business methods. One-third of the patent families in this technology have protection in Japan, and protection has been sought in Europe for fewer than one-third. Canada ranks fourth; only about 6 percent of patent families have protection in that country.

Figure 6-30.
Internet-related business method patent families worldwide



See appendix table 6-17. *Science & Engineering Indicators – 2002*

Text table 6-8.
Total number of patent families seeking patent protection in each country or region during 1980-99: Internet-related business methods

Country/Region	Patent families
United States	847
Japan	530
Europe	505
Canada	90
China	68
South Korea	67
Australia	61
Latin America	49
Taiwan	21
South Africa	15
Israel	14
New Zealand	6
Other	24

SOURCE: "International Analysis of Internet-Related Business Methods Patenting," submitted to National Science Foundation by Mogee Research and Analysis Associates (Reston, VA, June 7, 2001).

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[38]Data for this section were drawn from DWPI, which covers patenting from more than 40 different countries and patent-granting authorities. Each DWPI record constitutes a patent family, thus avoiding the problem of double counting inventions that are patented in more than one country.

DWPI began comprehensive coverage of Japanese patenting in this technology area in 1996. Therefore, the search was limited to records with an earliest priority year of 1995. (Most priority applications filed in 1995 would not be published, and hence appear in the database, until 1996 or later. Priority applications filed before 1995 could be published before 1996 and consequently miss some Japanese patents.)

The set of Internet-related business method patent families was formed from the intersection of the set of business method patents with the set of Internet patents. Only the records with priority years from 1995 through the present were selected for this analysis.

[39]Because of the time lag between patent application and publication, data for 1999 and 2000 should be regarded as incomplete.

[40]Any family with either an EPO patent or a patent in any European country was counted as having protection in Europe. Only the top countries and regions (those where protection has been sought for more than five total patent families) are presented in text table 6-8. "Latin America" refers to patents filed in Mexico, Brazil, or Argentina.

Patenting of Internet Business Methods in the United States, Japan, and Europe

Patent applications worldwide for methods of conducting business on the Internet grew rapidly in the late 1990s. Because business methods and algorithms were not considered patentable in the United States, Europe, or Japan, these applications quickly became controversial.

In the United States, business methods were excluded from patentability based on a series of court decisions beginning in the early 20th century. The Court of Appeals of the Federal Circuit struck down these exclusions in *State Street Bank & Trust Co. v. Signature Financial Group, Inc.* (1998) and *AT&T Corp.* v. *Excel Communications* (1999). As a result of these two cases, software or software-enabled inventions are considered patentable if they can be shown to have a practical application. According to some observers, these decisions left open the possibility that "pure" business methods (i.e., those without hard technology, such as computers), are patentable.

The ensuing surge in patent applications for business methods led to high-profile patent litigation cases and fueled a debate over whether business methods should be patentable at all, and, if so, whether business methods that are merely computerized versions of known business techniques or do not involve hard technology should be patentable. Behind these questions lurked the perennial disagreement over whether patents in general, and these patents in particular, help or hurt innovation.

A related issue was whether patents for business methods being granted by the Patent and Trademark Office (PTO) met the general criteria of novelty, utility, and nonobviousness. Critics accused PTO of granting patents for business methods that were obvious or overly broad. PTO responded by hiring examiners with expertise in business practices, improving search methods and resources, and expanding quality review sampling.

Congress contributed to the debate by including provisions in the 1999 American Inventors Protection Act to protect companies using business methods they did not believe were patentable that were later patented by another company. In 2000, the Business Method Patent Improvement Act (H.R. 5364) was introduced in the House of Representatives to make these patents more difficult to obtain and easier to challenge. The bill covers patents for both software- and nonsoftware-enabled business methods. The bill did not pass in 2000 but was reintroduced as H.R. 1333 in 2001.

The European Patent Office (EPO) as well as many European national patent offices formally exclude patents for software and business methods. Article 52(2) of the European Patent Convention expressly excludes software and business methods from the list of patentable inventions. This exclusion has had little practical effect on software inventions because a product or method that is of "technical character" may be patentable even if it involves software. Because determining "technical effect" is difficult, EPO has granted very few business method patents.

In late 2000, EPO changed its practice regarding business methods patents after a decision by the Board of Appeal. In a case involving IBM, the Board stated: "a computer program product is not excluded from patentability if, when run on a computer, it produces a 'technical effect' that goes beyond the normal physical interactions between program and computer." Despite the change in EPO practice, a November 2000 Diplomatic Conference to revise the European Patent Convention failed to delete the exclusion on software patenting, reflecting the disagreement remaining in Europe on this issue.

In December 2000, the Japanese Patent Office (JPO) published new policies and examination standards on patenting of algorithms and business methods that use algorithms. Previously, JPO excluded inventions classified as mathematical algorithms, natural laws, mathematical expressions of natural laws, or inventions that result in "mere processing of information by a computer" unless the application showed how the invention used the computer's resources in the processing. Current JPO policy considers most business methods inventions as forms of software inventions: "An invention, whether it is business-related or not, can be subject to a patent as a software-related invention if it meets certain requirements, such as involving information processing that uses computer hardware resources in order to solve a problem." Pure business methods per se, however, are not patentable: "The systematization of existing human transactions shall be deemed as not involving an inventive step and thus lack patentability, if it can be realized by routine application of usual system analysis and system design technologies, since it would be within the exercise of ordinary creative ability expected of a person skilled in the art to which the invention pertains."

In June 2000, the members of the Trilateral Patent Offices (PTO, EPO, and JPO) released a comparative examination of hypothetical computer-implemented business method patent claims. Despite the differences in their systems, the offices tended to make the same judgment on whether an application should be patented. The report concluded that a technical aspect is necessary for a computer-related business method to be eligible for patenting. EPO and JPO require that this technical aspect, typically a computer-related aspect, be expressed in the claim, whereas PTO allows it to be implicitly in the claim. The offices also confirmed that mere automation of a business process that had been known as a manual process, by way of using a well-known automation method, is not considered patentable. Thus, although the rules governing patenting of Internet business methods in the United States, Japan, and Europe are beginning to converge, important differences remain.

Number of Organizations Assigned Patents. The number of organizations in a country that are active in a technology may indicate that country's level of technological capability.[41]

Every year since 1995, the United States has had the most organizations actively filing patent applications for Internet business methods. (See figure 6-31 and appendix table 6-18.) During 1997–99, the United States averaged between 100 and 200 active assignees per year, two to four times the number of patenting organizations as Japan, which has ranked second in the number of active patenting organizations every year since 1995 and now has about 50 organizations per year filing priority applications in this technology. Trailing well behind are Germany, Great Britain, and Australia; these countries have between 3 and 10 organizations filing priority applications each year.

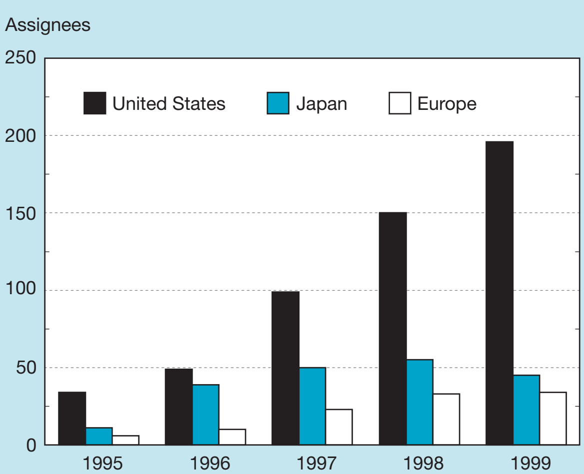
Text table 6-9 shows that in every country covered by this study, almost all the assignees are corporations or individual inventors. The United States is the only country in which universities consistently patent Internet business methods.[42] South Korea and Japan show occasional patenting activity from government agencies in this field. EPO, Finland, and Sweden show less activity from individuals than the other patent offices covered.

Highly Cited Patents. Since 1995, the United States has accounted for about 50 percent of all patent families for Internet business methods but more than 71 percent of the highly cited patent families. (See text table 6-10.) Thus, the United States has about 40 percent more of the highly cited patents in this field than one would expect based on its overall level of activity. This indicates not only that the United States is generating large numbers of patents in this field but also that these patents have technological significance for those inventions that follow. Unlike the United States, Japan has been significantly underrepresented among the most highly cited patents in this technology relative to its overall level of activity. Although Japan accounts for about 27 percent of all patent families, it accounts for only 6.8 percent of the cited families. One possible explanation for this is that about 85 percent of Japan's patent families are protected only in Japan, and such patents may be less likely to be cited by EPO examiners. Among the other countries that account for at least 2 percent of total patent families in this technology, Germany is significantly overrepresented among the cited patent families with about 50 percent more cited families than would be expected based on its overall level of patenting activity. Canada is significantly underrepresented among the cited patents, and Great Britain has about the number of cited patents expected based on its overall level of activity in this field. Care should be taken not to read too much into the ratios for countries with low levels of activity because one or two highly cited patents from these countries may make them appear to be overrepresented among the highly cited families.

[41]This refers to the number of unique organizations that have filed patent applications, not the number of applications they have filed. Data for 1999 and 2000 should be considered incomplete because of the 18-month time lag between the date a patent application is filed and the date it is published.

[42]Like those presented for human DNA sequence patents discussed earlier, data reflect the number of unique organizations filing patent applications, not the number of applications they have filed. Individuals are counted only if no other type of organization also was on the patent.

Figure 6-31.
Active assignees for Internet-related business methods patents, United States, Japan, and Europe



See appendix table 6-18. *Science & Engineering Indicators – 2002*

Venture Capital and High-Technology Enterprise

One of the most serious challenges to new entrepreneurs is capital, or the lack thereof. Venture capitalists typically make investments in small, young companies that may not have access to public or credit-oriented institutional funding. Venture capital investments can be long term and high risk, and they may include hands-on involvement in the firm by the venture capitalist. Venture capital can aid the growth of promising small companies and facilitate the introduction of new products and technologies, and it is an important source of funds for the formation and expansion of small high-technology companies. This section examines investments made by U.S. venture capital firms by stage of financing and by technology area.

The latest data show total venture capital under management rising vigorously each year from 1996 through 2000. The largest one-year increase occurred in 1999, when the pool of venture capital jumped to nearly $145.2 billion, a 72.5 percent gain from the previous year. In 2000, once again, the pool of venture capital grew sharply, rising 60.9 percent to $233.7 billion, more than six times the amount managed only five years earlier.[43]

The amount of capital managed by venture capital firms grew dramatically during the 1980s as venture capital emerged as an important source of financing for small, innovative firms. (See text table 6-11.) By 1989, the capital managed by venture capital firms totaled nearly $33.5 billion, up from almost $4.1 billion in 1980. The number of venture capital firms also grew

[43]According to a recent report from the National Venture Capital Association (2001), new money coming into venture capital funds slowed down during the last quarter of 2000 following several quarters of lackluster returns to investors in venture captial funds.

Text table 6-9.
Active assignees, by priority country and priority year: Internet-related business methods patents

Priority country	1995	1996	1997	1998	1999	2000
Australia						
Corporations	2	2	3	7	10	0
Universities	0	0	0	0	0	0
Not for profits	0	0	0	0	0	0
Government agencies	0	0	1	0	0	0
Individuals	0	1	2	1	3	0
Canada						
Corporations	1	0	3	5	3	0
Universities	0	0	0	1	0	0
Not for profits	0	0	0	0	0	0
Government agencies	0	0	0	0	0	0
Individuals	3	0	1	3	3	0
Germany						
Corporations	2	2	2	8	10	2
Universities	0	0	0	0	0	0
Not for profits	0	0	1	0	0	0
Government agencies	0	0	0	0	0	0
Individuals	0	1	2	7	7	2
European Patent Office						
Corporations	1	0	2	4	1	0
Universities	0	0	0	0	0	0
Not for profits	0	0	0	0	0	0
Government agencies	0	0	0	0	0	0
Individuals	0	0	1	0	0	0
Finland						
Corporations	1	2	0	3	7	0
Universities	0	0	0	0	0	0
Not for profits	0	0	0	0	0	0
Government agencies	0	0	0	0	0	0
Individuals	0	0	1	0	1	0
France						
Corporations	0	1	3	5	2	0
Universities	0	0	0	0	0	0
Not for profits	0	0	0	0	0	0
Government agencies	0	0	0	0	0	0
Individuals	2	1	1	3	2	0
Great Britain						
Corporations	1	2	7	8	8	1
Universities	0	0	0	0	0	0
Not for profits	0	0	0	0	0	0
Government agencies	0	0	0	0	0	0
Individuals	0	1	1	3	6	0
Japan						
Corporations	11	39	49	54	44	4
Universities	0	0	0	0	0	0
Not for profits	0	0	0	0	0	0
Government agencies	0	0	0	1	1	0
Individuals	0	7	5	5	7	1
South Korea						
Corporations	2	1	3	4	0	0
Universities	0	0	0	0	0	0
Not for profits	0	0	0	0	0	0
Government agencies	1	0	1	1	0	0
Individuals	1	0	0	2	10	0
Sweden						
Corporations	0	1	6	2	2	0
Universities	0	0	0	0	0	0
Not for profits	0	0	0	0	0	0
Government agencies	0	0	0	0	0	0
Individuals	0	0	0	2	0	0
United States						
Corporations	33	47	98	148	195	1
Universities	1	1	1	2	1	0
Not for profits	0	1	0	0	0	0
Government agencies						
Individuals	8	22	47	34	33	0
Other						
Corporations	2	3	7	21	13	2
Universities	0	2	0	0	0	0
Not for profits	0	1	0	1	0	0
Government agencies						
Individuals	3	1	10	13	13	4

NOTE: Priority country is established by the location of the original patent application.

SOURCE: "International Analysis of Internet-Related Business Methods Patenting," submitted to National Science Foundation by Mogee Research and Analysis Associates (Reston, VA, June 7, 2001).

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Text table 6-10.
Priority countries ranked by share of top-cited patents: Internet-related business methods, 1995-99

Priority country	Share of top cited (%)	Share of total families (%)	Ratio top cited to total families
United States	71.2	50.3	1.4
Japan	6.8	27.1	0.3
Germany	5.5	3.6	1.5
Finland	4.1	0.9	4.4
European Patent Office	2.7	0.9	2.9
Great Britain	2.7	3.0	0.9
Australia	1.4	2.2	0.6
Canada.............	1.4	1.4	1.0
Denmark...........	1.4	0.1	11.2
Ireland	1.4	0.4	3.7
Netherlands.......	1.4	0.9	1.6

NOTE: Priority country is established by the location of the original patent application.

SOURCE: "International Analysis of Internet-Related Business Methods Patenting," submitted to National Science Foundation by Mogee Research and Analysis Associates (Reston, VA, June 7, 2001).

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Text table 6-11.
Venture capital under management in United States: 1980–2000
(Millions of U.S. dollars)

Year	New capital committed	Total venture capital under management
1980	2,073.6	4,071.1
1981	1,133.2	5,685.7
1982	1,546.4	7,758.7
1983	4,120.4	12,201.2
1984	3,048.5	15,759.3
1985	3,040.0	19,330.6
1986	3,613.1	23,371.4
1987	4,023.9	26,998.5
1988	3,491.9	29,539.2
1989	5,197.6	33,466.9
1990	2,550.4	34,000.9
1991	1,488.0	31,587.2
1992	3,392.8	30,557.3
1993	4,115.3	31,894.0
1994	7,339.4	34,841.3
1995	8,426.7	38,465.0
1996	10,467.2	46,207.2
1997	15,175.6	59,614.5
1998	25,292.6	84,180.1
1999	60,138.4	145,195.6
2000	93,436.1	233,666.1

SOURCE: Special tabulations provided by Venture Economics (Newark, NJ, March 2001).

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during the 1980s from around 448 in 1983 to 670 in 1989.

In the early 1990s, the venture capital industry slowed as investor interest waned and the amount of venture capital disbursed to companies declined. The number of firms managing venture capital also declined during the early 1990s. The slowdown was short lived, however; investor interest picked up in 1992 and the pool of venture capital has grown steadily since then.

California, New York, and Massachusetts together account for about 65 percent of venture capital resources. Venture capital firms tend to cluster around locales considered to be hotbeds of technological activity as well as in states where large amounts of R&D are performed (Venture Economics Information Services (VEIS) 1999).[44] See sidebar, "Business Incubators Nurture Future Entrepreneurs on U.S. Campuses."

Venture Capital Commitments and Disbursements

Several years of high returns on venture capital investments have stimulated increased investor interest. This interest soared after 1995, with new commitments rising 24.2 percent in 1996 to nearly $10.5 billion and then rising 45.0 percent the following year. By 2000, new commitments reached $93.4 billion, more than 10 times the amount available in 1995. Pension funds remain the single largest supplier of committed capital, supplying 41 percent in 2000. (See text table 6-12.) Banks and insurance companies are the next largest source, supplying 23 percent of committed capital, followed closely by endowments and foundations at 21 percent (VEIS 1999).[45]

Starting in 1994, new capital raised exceeded capital disbursed by the venture capital industry. In each of the following years, that gap has grown larger, creating surplus funds available for investments in new or expanding innovative firms. As early as 1990, firms producing computer software or providing computer-related services received large amounts of new venture capital, but they became the clear favorite beginning in 1996. (See figure 6-32 and appendix table 6-19.) In 1990, software companies received 17.4 percent of all new venture capital disbursements, nearly twice the share going to computer hardware companies and biotechnology companies. That share rose to about 27.1 percent in 1993 and then fluctuated between 16.4 and 27.1 percent until 1998, when software companies received more than one-third of all venture capital disbursements. Telecommunications companies also attracted large amounts of venture capital during the 1990s, edging out software companies for the lead in 1992 and 1994. Medical and health care companies received a large share of venture capital throughout the 1990s, reaching a high of 17.8 percent in 1994 before dropping to 13.6 percent in 1998. Computer hardware companies, an industry highly favored by the venture capitalists during the 1980s, received only 2.4 percent of total venture capital disbursements in 2000.

The latest data include a new category that makes comparisons with previous years more difficult. In the late 1990s, the Internet emerged as a key new tool for business, and com-

[44]Data on U.S. R&D performance by state are presented in chapter 4.
[45]Based on information contained in Venture Economics (1999).

Text table 6-12.
Capital commitments by limited partner type: 1990–2000
(Billions of dollars)

Limited partner type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total commitment	2.55	1.49	3.39	4.12	7.34	8.43	10.47	15.18	25.29	60.14	93.44
Pension funds	1.34	0.63	1.41	2.43	3.36	3.12	5.74	5.77	15.03	26.16	37.47
Financial and insurance	0.24	0.08	0.49	0.43	0.70	1.62	0.30	0.91	2.59	9.32	21.77
Endowments and foundations	0.32	0.36	0.63	0.44	1.57	1.65	1.18	2.43	1.58	10.34	19.72
Individuals and families	0.29	0.18	0.37	0.30	0.87	1.36	0.68	1.82	2.83	5.77	11.03
Corporations	0.17	0.06	0.11	0.34	0.67	0.35	1.98	3.64	2.97	8.54	3.46
Foreign investors	0.19	0.17	0.38	0.18	0.18	0.32	0.59	0.61	0.29	NA	NA

NA = not available

SOURCE: Special tabulations provided by Venture Economics (Newark, NJ, March 2001).

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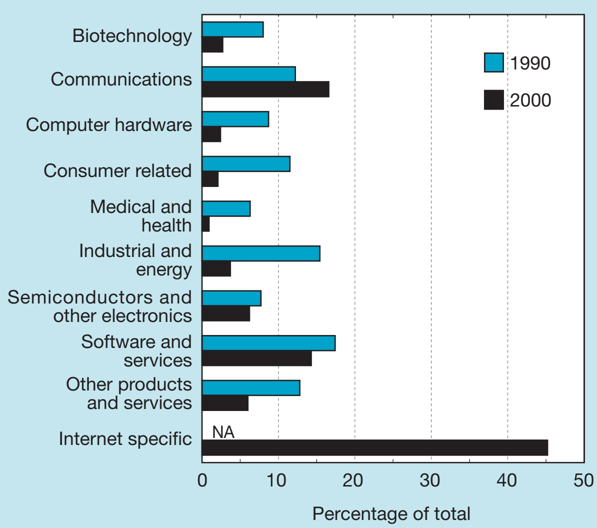
Figure 6-32.
U.S. venture capital disbursements, by industry category



NA = not available

See appendix table 6-19. *Science & Engineering Indicators – 2002*

panies developing Internet-related technologies drew venture capital investments in record amounts. Beginning in 1999, investment dollars disbursed to Internet companies were classified separately in the statistics that track venture capital investment trends. Before 1999, some of these investments would have been classified as going to companies involved in computer hardware, computer software, or communications technologies.

In 1999, Internet companies became the leading recipients of venture capital funds, collecting 41.7 percent of all venture capital disbursed. The latest data show their share increasing to 45.2 percent in 2000. Computer software companies, the leader through much of the 1990s, drew 12.9 percent of all venture capital disbursed in 1999 and 14.3 percent in 2000. The share of investments going to communications companies averaged 16.5 percent in 1999 and 2000.

Venture Capital Investments by Stage of Financing

The investments made by venture capital firms may be categorized by the stage at which the financing is provided (VEIS 1999). Early-stage financing involves the following:

- **Seed financing—**usually involves a small amount of capital provided to an inventor or entrepreneur to prove a concept. Seed financing may support product development but rarely is used for marketing.
- **Startup financing—**provides funds to companies for use in product development and initial marketing. This type of financing usually is provided to companies that are newly organized or have been in business for a short time and have not yet sold their product in the marketplace. Generally, such firms have already assembled key management, prepared a business plan, and conducted market studies.
- **First-stage financing**—provides funds to companies that have exhausted their initial capital and need funds to initiate commercial manufacturing and sales.

Later stage financing includes the following:

- **Expansion financing—**includes working capital for the initial expansion of a company; funds for major growth expansion (involving plant expansion, marketing, or development of an improved product); and financing for a company expecting to go public within six months to a year.
- **Acquisition financing—**provides funds to finance the purchase of another company.

- **Management/leveraged buyout**—includes funds to enable operating management to acquire a product line or business from either a public or private company. These companies often are closely held or family owned.[46]

Most venture capital disbursements are directed to later stage investments. Since 1982, later stage investments captured between 59 and 79 percent of venture capital disbursements, with the high and low points both reached in the 1990s. In 2000, later stage investments represented 78 percent of total disbursements. (See figure 6-33 and appendix table 6-20.) Capital for company expansions attracted the most investor interest by far; this financing stage alone attracted more than half of all venture capital disbursed since 1995. In 2000, venture capital funds to finance company expansions accounted for 61 percent of total disbursements. Nearly half (48.1 percent) of the $55.2 billion disbursed by venture capital funds to finance expansions of existing businesses in 2000 went to Internet companies.

Contrary to expectations, only a relatively small amount of venture capital helps struggling inventors or entrepreneurs prove a concept or develop their products. During the 21-year period examined, such seed money never accounted for more than 6 percent of all venture capital disbursements and most often represented between 2 and 4 percent of the annual totals.[47] The latest data show the share of all venture capital disbursements classified as seed financing falling to its lowest level ever, representing just 1.4 percent of all venture capital in both 1999 and 2000. Nevertheless, nearly $1.3 billion in seed money was disbursed by venture capital funds in 2000, up from $710.7 million in 1999 and $312.5 million in 1995.

Computer software, telecommunications technologies, and medical and health-related firms were the largest recipients of venture capital seed-type financing during the late 1990s.

[46]For the acquisition financing and management/leveraged buyout categories, data include only capital disbursements made by a venture capital firm and do not include such investments made by a buyout firm.

[47]A study of new firms in the southwestern United States found that many were able to obtain substantial amounts of initial capital through strategic alliances with more established firms (Carayannis, Kassicieh, and Radosevich 1997). The study indicated that embryonic firms raised more than $2 million, on average, in early-stage financing through such strategic alliances.

Business Incubators Nurture Future Entrepreneurs on U.S. Campuses

The term "business incubator" can describe a wide range of institutions whose purpose is to help develop new and nurture established small business enterprises. According to data compiled by the National Business Incubation Association (NBIA), in 1980 as few as 12 business incubators were operating in North America; in 1998, there were more than 800 (National Business Incubation Association 2001).

Business incubators can be operated by universities, colleges and community colleges, for-profit businesses and economic development agencies, local governments, or a combination of all these organizations. Business incubators seek to encourage new entrepreneurs by consolidating, usually under one roof, many of the services critical to successful business development, including management advice, networking with other business owners, technical support, and access to financing.

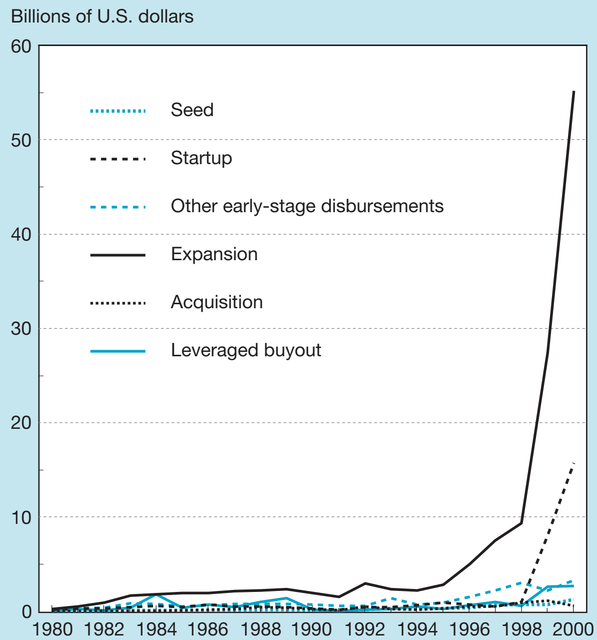
In 1998, according to data compiled by NBIA:

- 40 percent of incubators were technology focused.
- 45 percent were urban, 36 percent were rural, and 19 percent were suburban.
- 27 percent were affiliated with universities and colleges either directly or as part of joint efforts among governments, private developers, and nonprofit agencies.

More than half of all incubators operating in 1998 were sponsored by government and nonprofit organizations. These incubators tend to focus on local economic development and job creation. Such "targeted" incubators accounted for about 9 percent of the total in 1998.

Data on numbers and characteristics of business incubators operating in the United States come from NBIA's website. The NBIA database offers the most current and complete data available but, according to its own estimates, likely understates the numbers of business incubators operating in 1998.

Figure 6-33.
U.S. venture capital disbursements, by stage of financing, 1980–2000



See appendix table 6-20. *Science & Engineering Indicators – 2002*

(See appendix table 6-21.) Computer software firms received the most seed money from 1996 to 1998 before relinquishing the top position to Internet companies in 1999 and 2000. Investments in Internet companies represented 60.8 percent of all seed money from venture capital funds in 1999 and 43.7 percent in 2000.

Communications firms gained favor with forward-looking venture capitalists in 2000, attracting 26.2 percent of all seed-stage investments disbursed by venture capital funds that year, up from just 5.0 percent in 1999. The shares of venture capital seed money going to computer software companies fell to 11.3 percent in 1999 and to 10.5 percent in 2000.

With more than 80 percent of seed money going to either Internet, communications, or computer software companies, seed money for companies involved in other technologies declined. Biotechnology, which in 1998 received 11.9 percent of the venture capital disbursed as seed money, saw its share drop to 6.3 percent in 1999 and 0.9 percent in 2000. Medical and health-related firms fared better than biotechnology firms, yet they saw their share drop from 20 percent in both 1997 and 1998 to 6.9 percent in 1999 and 2.9 percent in 2000.

Chapter Summary: Assessment of U.S. Technological Competitiveness

Based on various indicators of technology development and market competitiveness, the United States continues to lead, or to be among the leaders, in all major technology areas. Advances in information technologies (i.e., computers and telecommunications products) continue to influence new technology development and dominate technical exchanges between the United States and its trading partners.

Although economic problems continue to hamper further progress, Asia's status as both a consumer and developer of high-technology products is enhanced by the development taking place in many Asian economies, particularly Taiwan and South Korea. Several smaller European countries also exhibit growing capacities to develop new technologies and to compete in global markets.

The current position of the United States as the world's leading producer of high-technology products reflects its success in both supplying a large domestic market and serving foreign markets. This success in the international marketplace may be the result of a combination of factors: the nation's long commitment to investments in S&T; the scale effects derived from serving a large, demanding domestic market; and the U.S. market's openness to foreign competition. In the years ahead, these same market dynamics may also benefit a more unified Europe and Latin America and a rapidly developing Asia and complement their investments in S&T.

Beyond these challenges, the rapid technological development taking place around the world also offers new opportunities for the U.S. S&T enterprise. For U.S. businesses, rising exports of high-technology products and services to Asia, Europe, and Latin America are already apparent and should grow in the years ahead. The same conditions that create new business opportunities—the growing global technological capacity and the relaxation of restrictions on international business—can also create new research opportunities. The well-funded institutes and technology-oriented universities that are being established in many technologically emerging areas of the world will advance scientific and technological knowledge and lead to new collaborations between U.S. and foreign researchers.

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